EbE Vertexing for Mixing

Alex

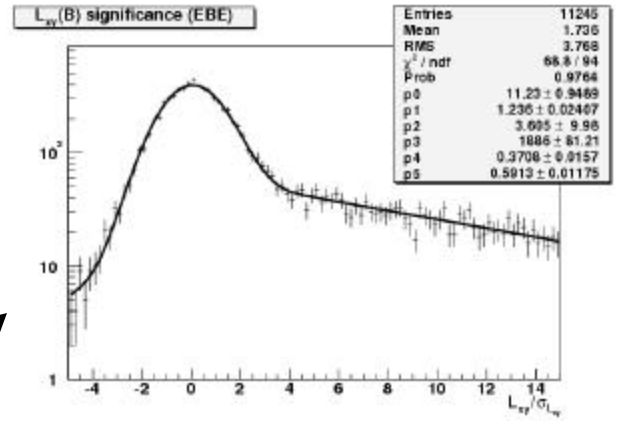
For the LBLB group

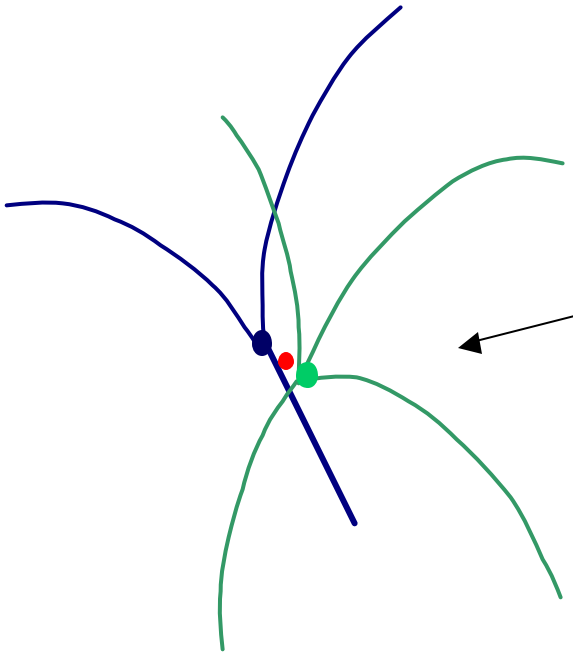
Status

- Increased sample's statistics
  - ✓ Full ~350 pb^{-1}
  - ✓ $D^0\pi$, $D^+\pi$, ψK^+, ψK^*, $\psi' \rightarrow \mu\mu\pi\pi$
- Primary Vertex:
  - ✓ SF robustly sitting around 1.38
  - ✓ Dependencies (Z,Pt,Si hits,Ntracks)
  - ✓ Effect of hourglass
  - ✓ G3X (no time to show today, but does not seem relevant with current statistics)
  - ✓ Systematics
  - ✓ Comparison of pulls and extraction of a common value:
    - D_0 vs L_{xy}
- Secondary Vertex:
  - ✓ Dependencies (Z,ϕ,η, Pt,L_{xy},ct,$\Delta\phi$,ΔR, Isolation,Si hits)
  - – Extraction of a common scale factor with systematics?

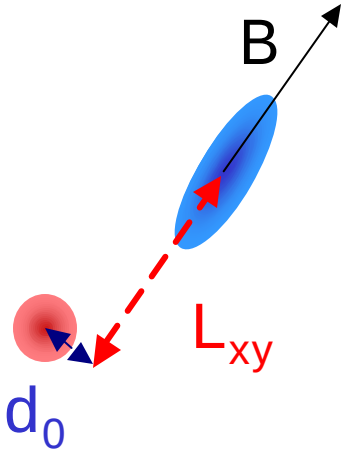
Primary Vertex

The tools





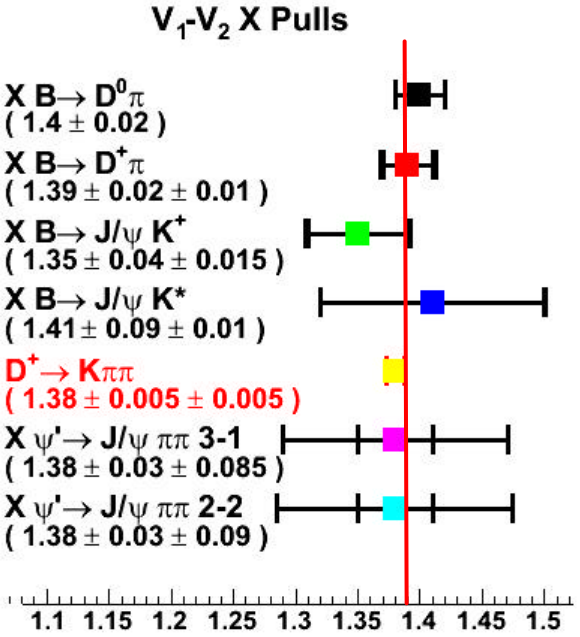
- Prompt peak
- V-truth
- V1-V2
- d_0/σ

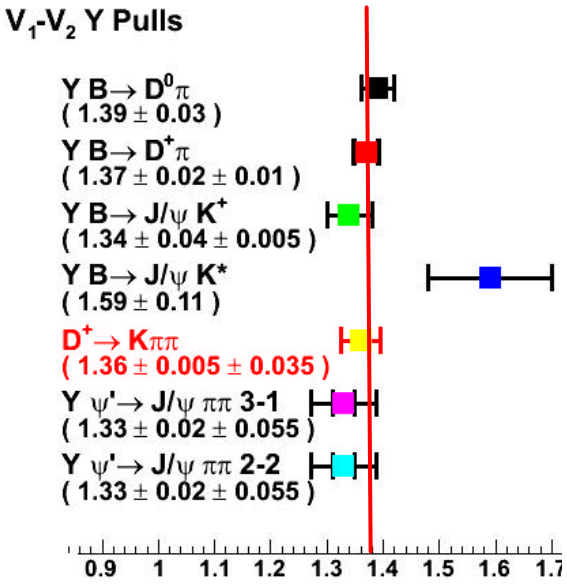


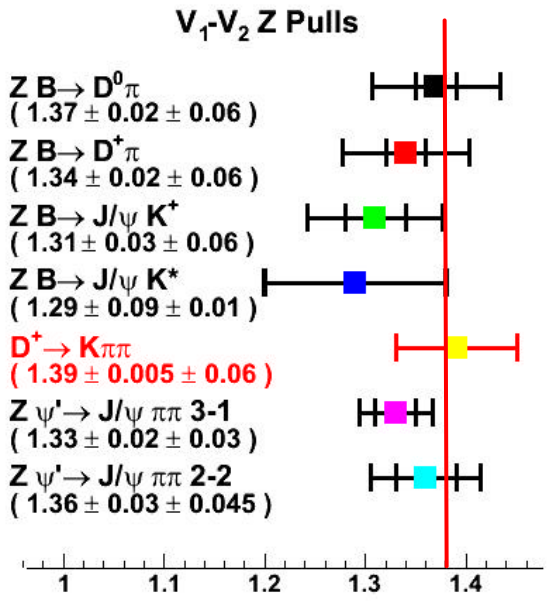
Scale Factor from V1-V2

- Fit two independent subsets of 'primary' [I.e. non-B] tracks
- Measure (x_1,y_1,z_1) and (x_2,y_2,z_2)
- Obtain Δ/σ for x, y and z
- Fit core with single gaussian (central value)
- Repeat fit with two gaussians ('syst.')
- Still using 1.38

For what follows





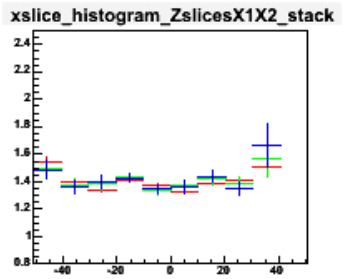


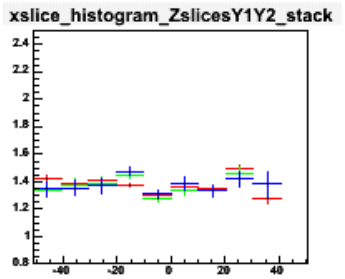
Is the PVSF 'universal'?

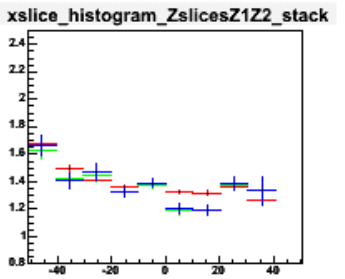
primvtx_sum_all.root

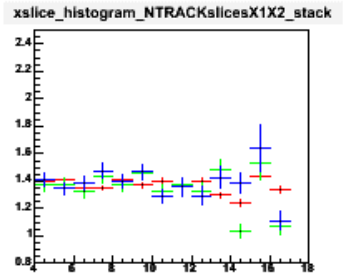
primvtx_sum_nodplus_all.root

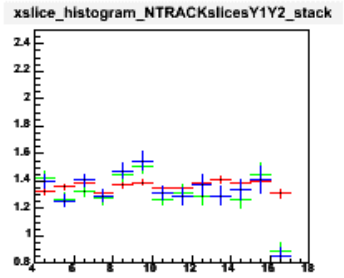
primvtx_sum_bonly.root

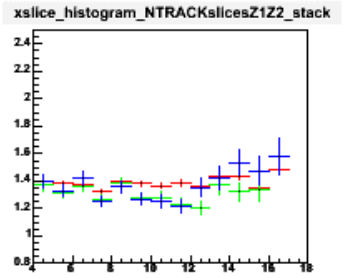


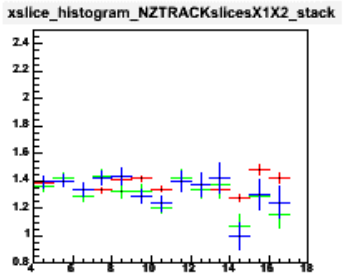


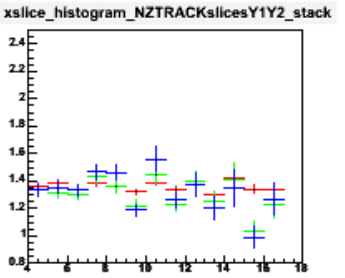


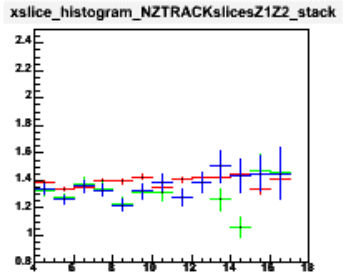


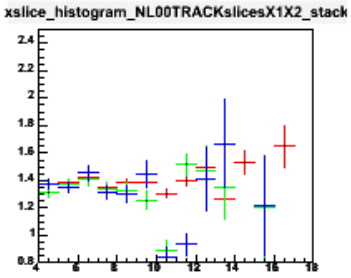


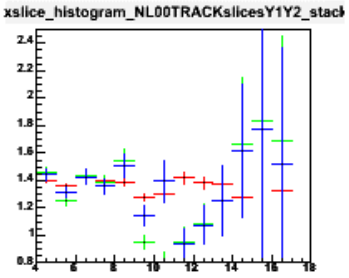


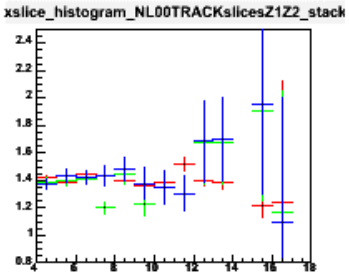


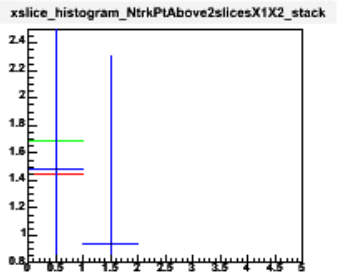


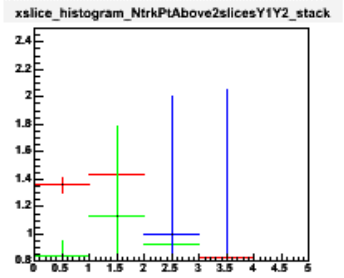


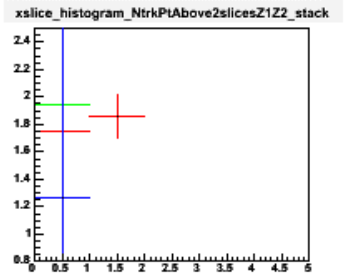


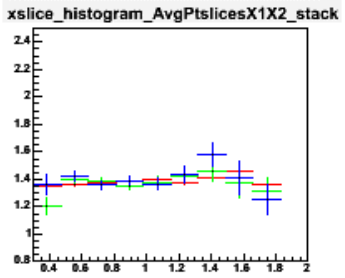


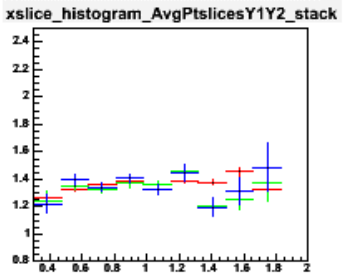


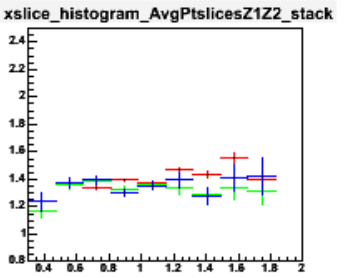




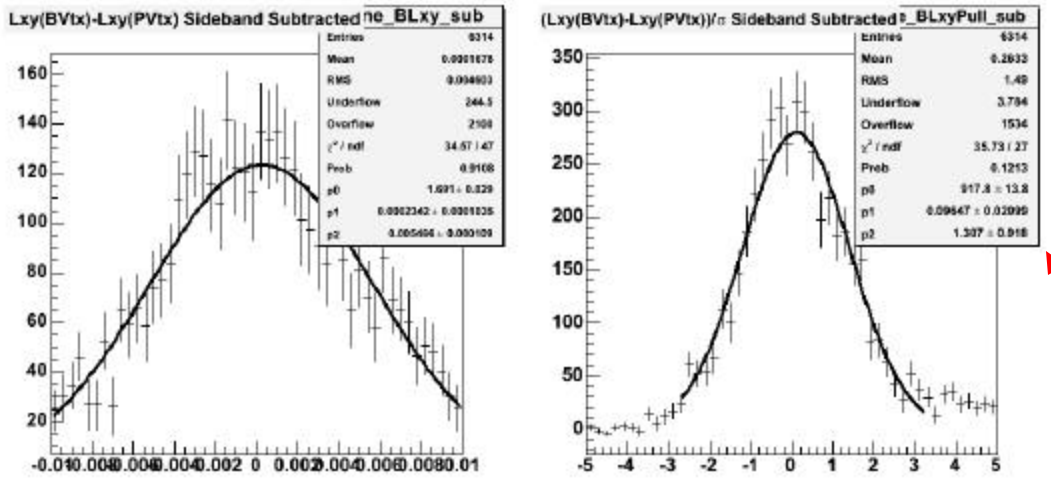


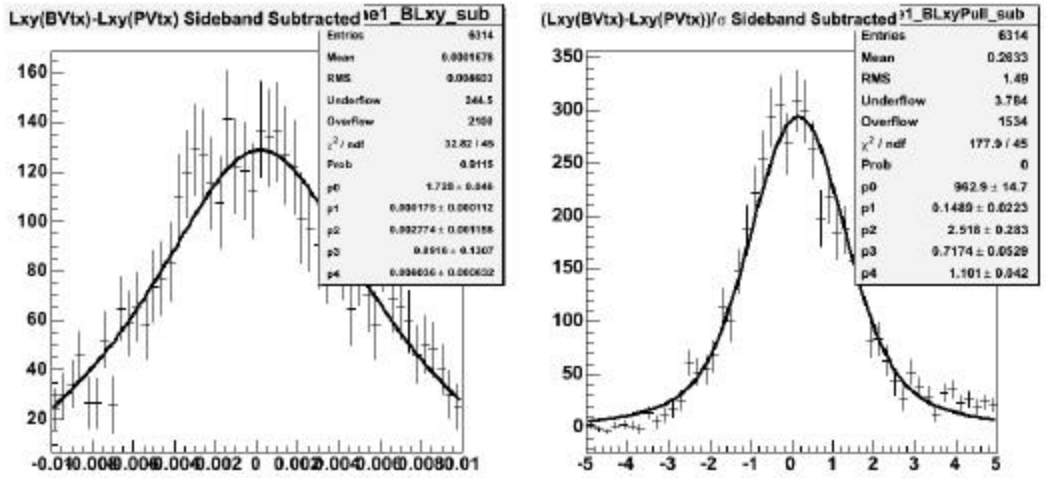






ψ' as a probe the PV scale factor





- Prompt production
- Lxy wrt EbE is 0!

1.31±0.02

1.01±0.04 (~86% of the distribution)

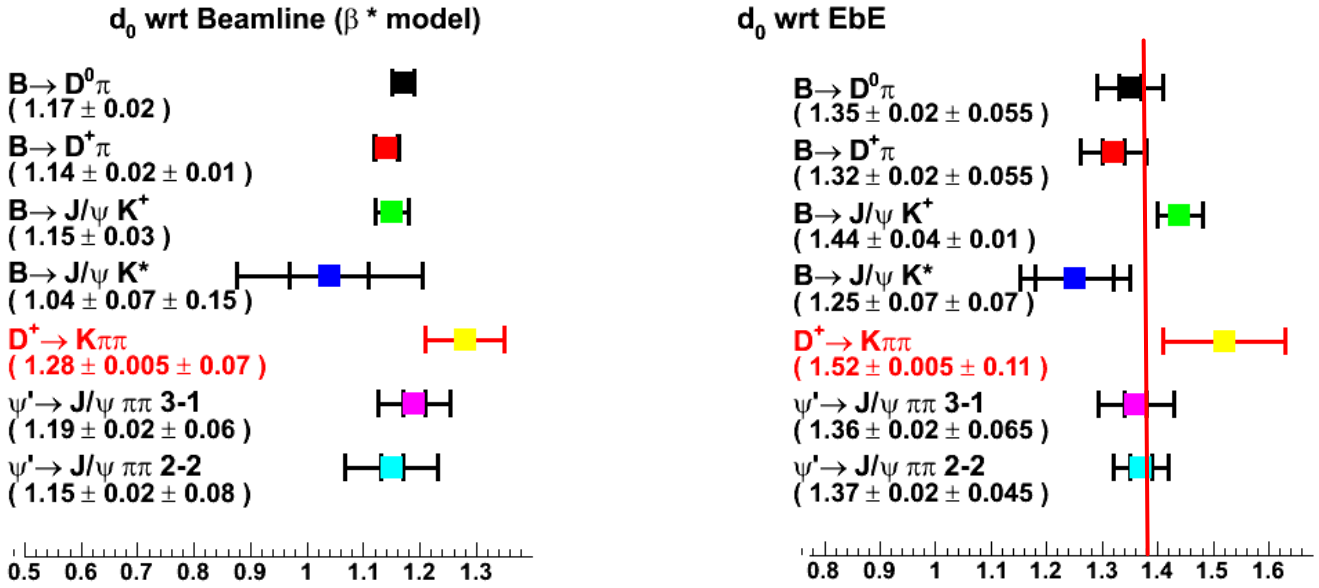
NB: the other studies indicate a SF of ~1.38 The number I get here with the systematic uncertainty is consistent. Systematic is wide because of the presence of displaced ψ'

Bottomline…

- PV Scale factor shows no strong dependence on variables probed
- Any other variable you want to see?
- We could be more accurate but remember that the statistics is limited!
- Focus on assessing systematics
  - Inter-sample variation
  - Change fit model (just like the overall fit)
- Will try to improve a little more on statistics ($K\pi\pi\pi$, $D\pi\pi\pi$), but mostly aiming at perfecting systematics

Do Impact Parameters Give a consistent picture?

- We can use the B I.P. pulls as cross check of the L_{xy} resolution…

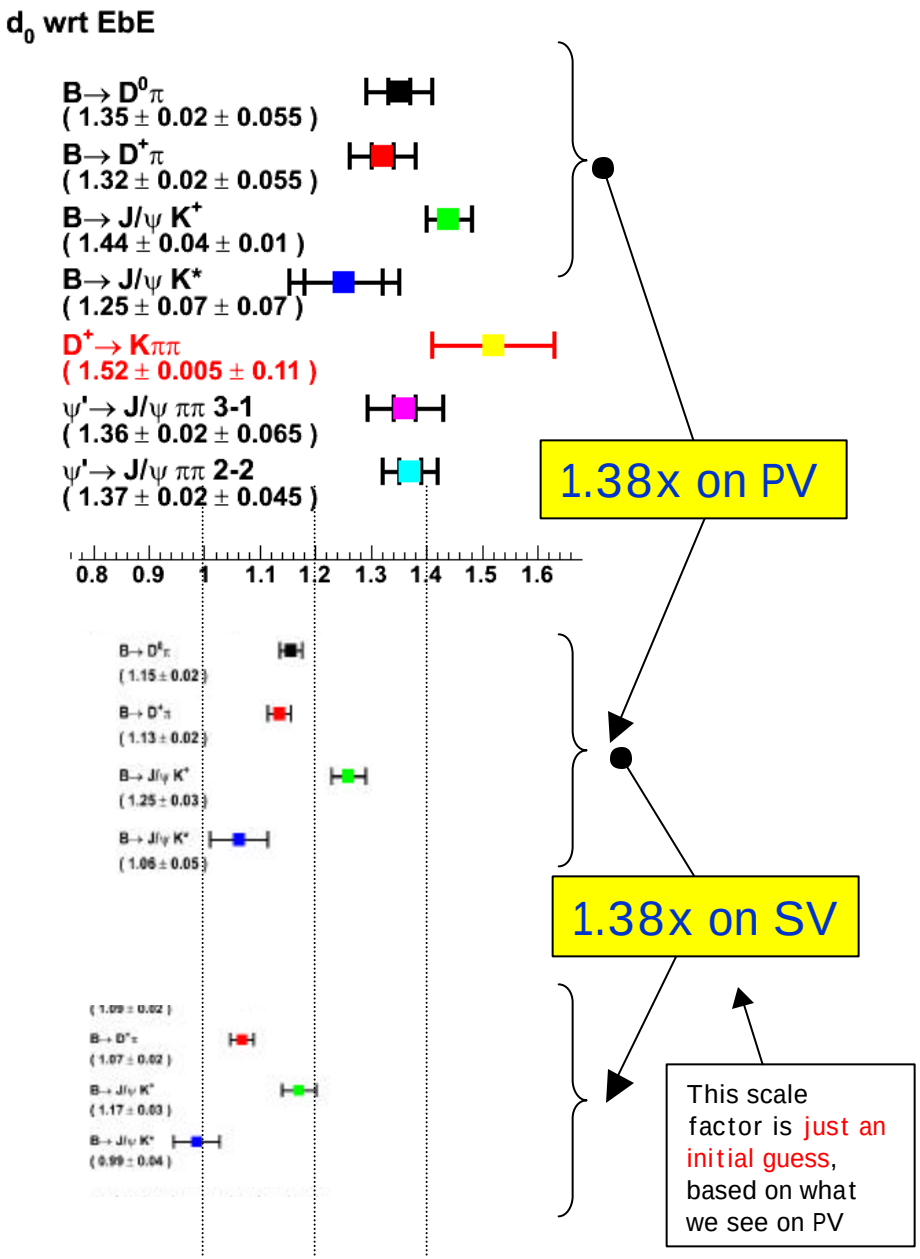


- Apply 1.38x and beamline constraint, check what happens:

For instance with $D^0\pi$: EbE: 1.35→1.15

- Unexpected? Not quite: see plot on the left!
- There are two additional sources that enter in both cases:
  - Hourglass parameterization (including time-dependancy: see Aart's talk)
  - A secondary vertex scale factor

Relevance of the SV scale factor



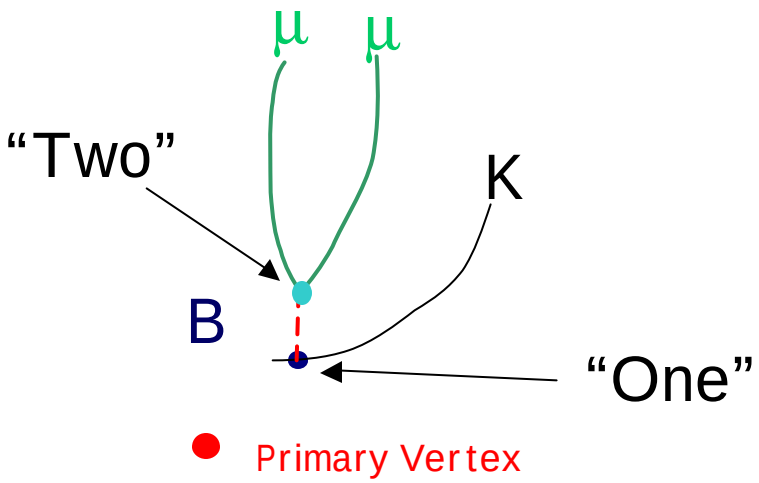
- d0/L_{xy} uncertainty is a combination of:
  - PV covariance
  - Beamline covariance
  - SV covariance
- So far only PV was discussed!
- PV scale factor is not the full story: when you bring down σ_{PV}, the importance of σ_{SV} increases
- Need to get the SV scale factor right!
- REM: **even if PVSF=SVSF, we cannot use one common L_{xy} SF (the beamline covariance enters too into the expression!)**

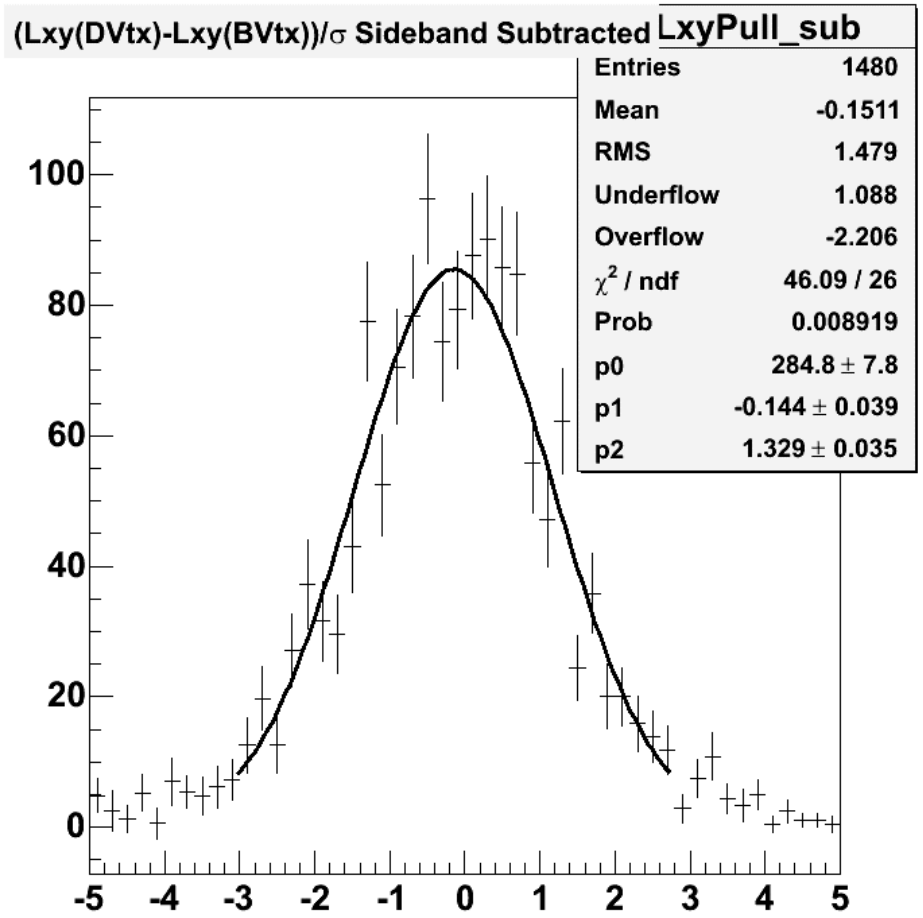
Secondary Vertex

Scale factor from B decays

Example: $B \rightarrow \psi K^+$

- Fit ψ to a single vertex
- "point" ψ back to K
- Measure L_{xy} wrt B vertex
- Pull is a proxy for a "seconday vertex" pull!



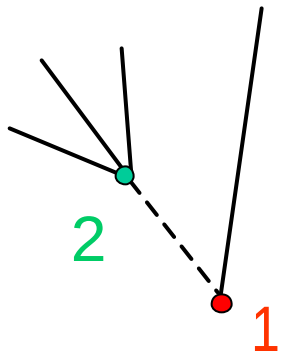


Samples and Topologies used:

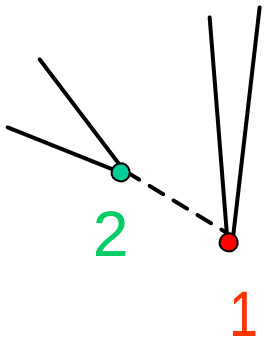
- $B \rightarrow \psi K^+$ (1:K 2:$\mu\mu$)
- $B \rightarrow \psi K^*$ (1:Kπ 2:$\mu\mu$)
- $D^+ \rightarrow K\pi\pi$ (1:π 2:Kπ)
- $\psi' \rightarrow \psi\pi\pi$ (1:μ 2:$\mu\pi\pi$)

(1:$\mu\pi$ 2:$\mu\pi$)

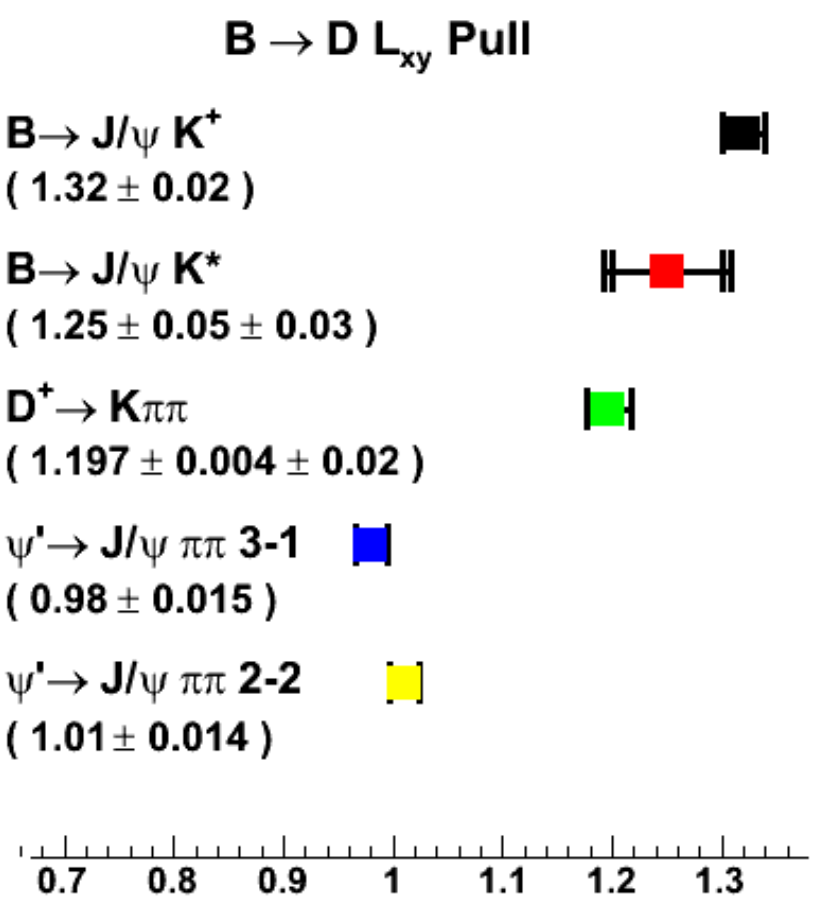
"3-1"



"2-2"



Bottomline for SV

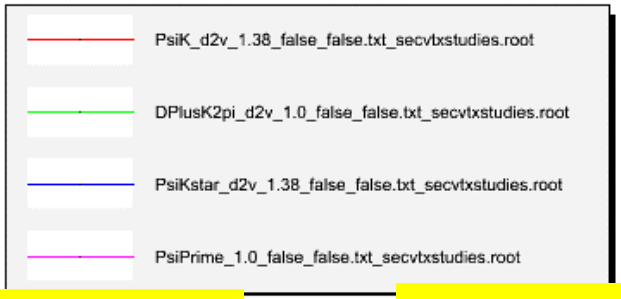


- Pull grows as a function of lifetime!@#^$!
- Hidden dependencies!
  - Detector acceptance?
  - Kinematics?
  - Multiplicity? (no: ψK*)

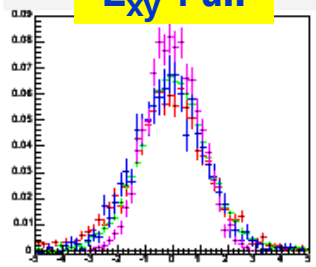
1. Figure out which distributions are different
2. Check dependency!

…results in the next pages

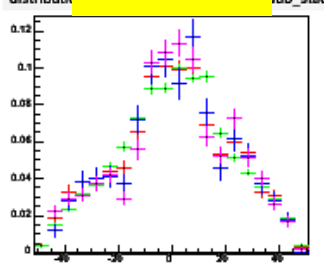
Distributions



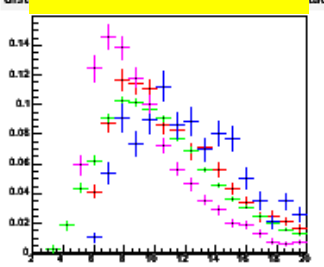
L_{xy} Pull



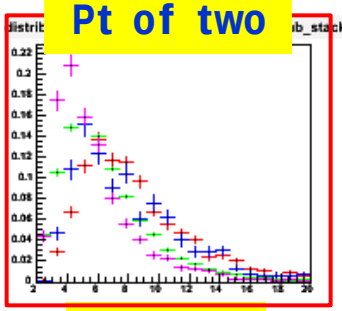
Z



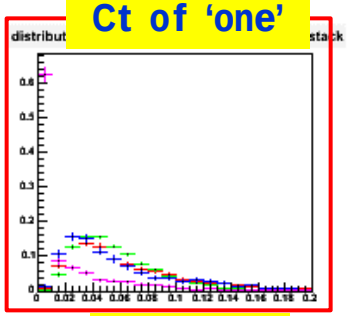
Pt of 'one'



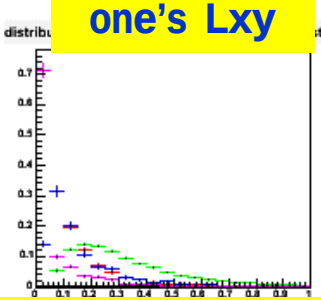
Pt of two



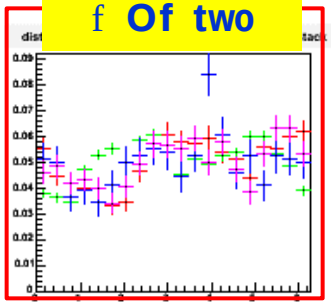
Ct of 'one'



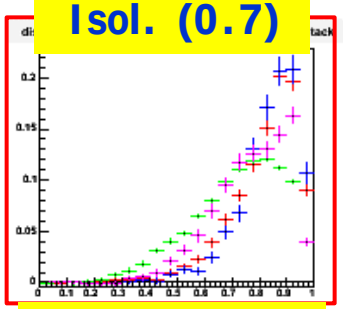
one's Lxy



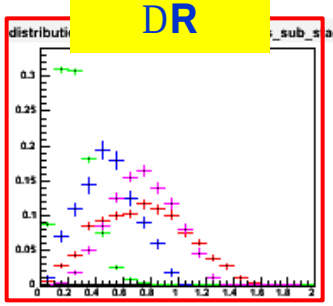
f Of two



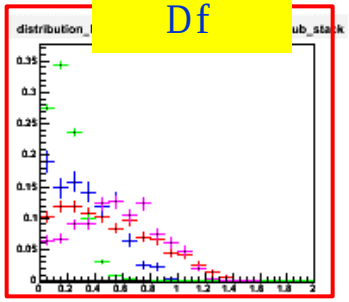
Isol. (0.7)



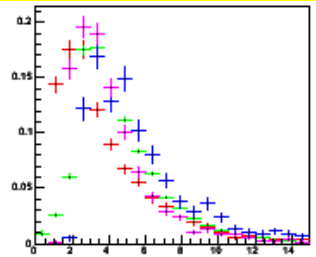
DR



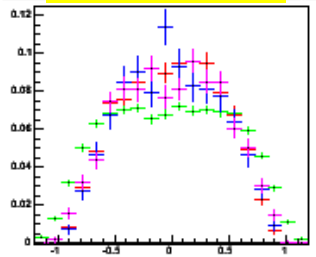
Df



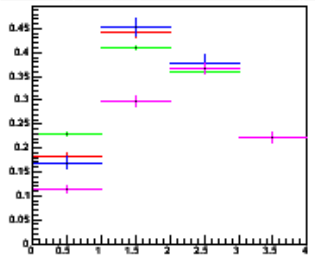
Pt one's tracks



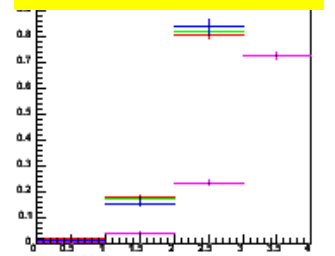
h Of two



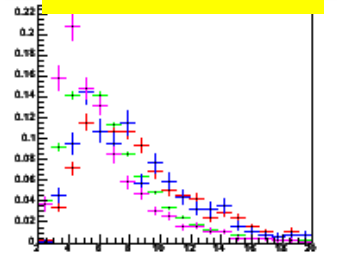
#L00 tracks



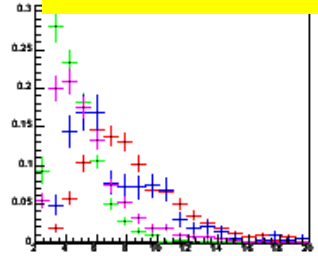
#stereo tracks



Pt at Df<0.15

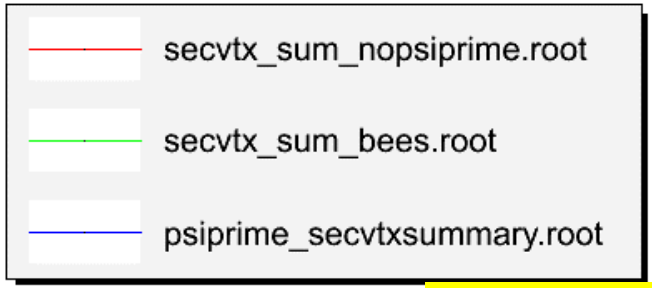


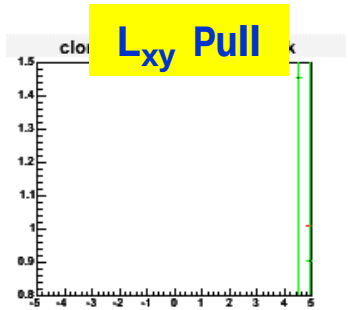
Pt at Df>0.15

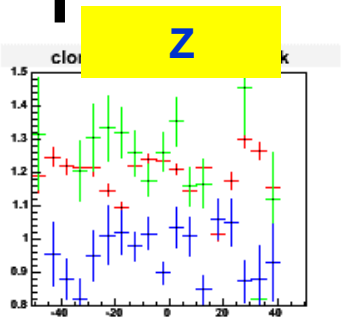


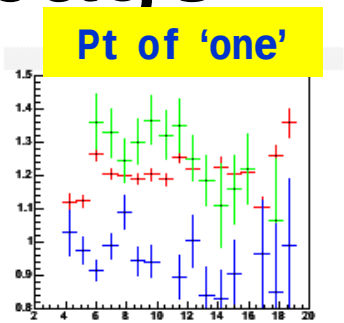
- Detector acceptance ($\phi\eta z$) pretty similar
- No clear difference in Si properties
- Kinematics differs ($\Delta\phi$ ΔR P_t)

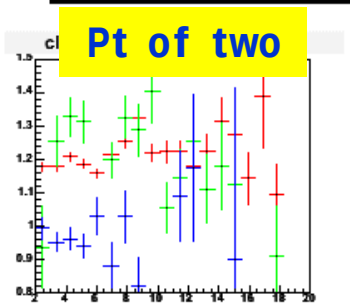
Pulls vs variables in prev. page

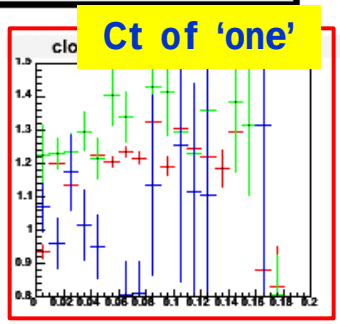


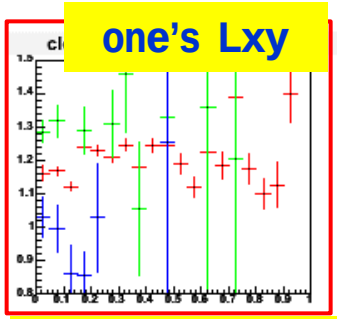


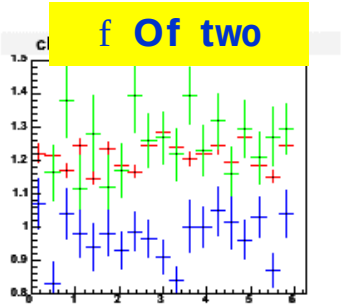


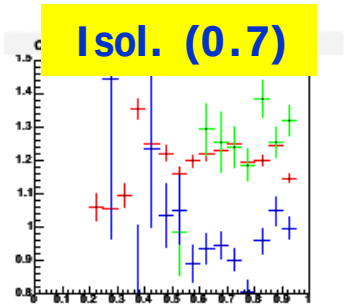


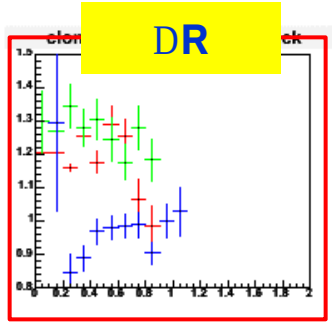


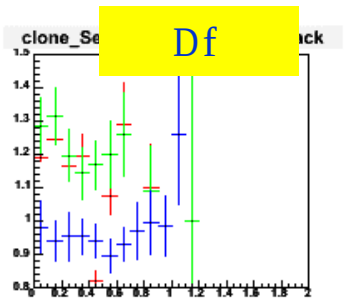


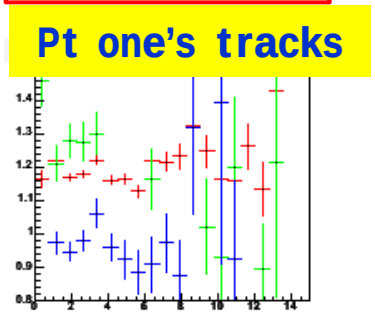


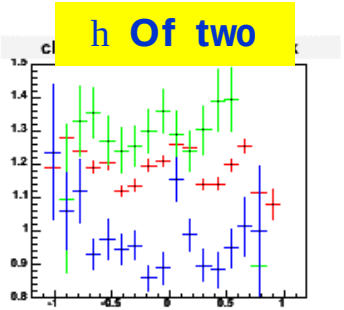


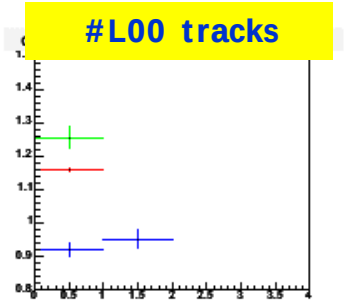


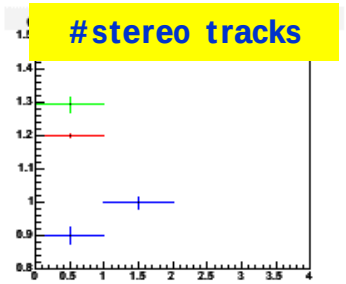


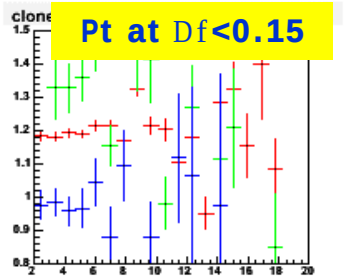


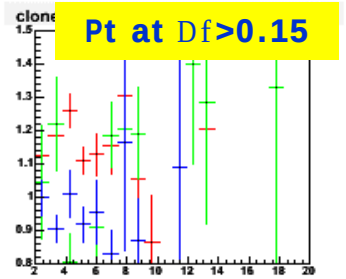








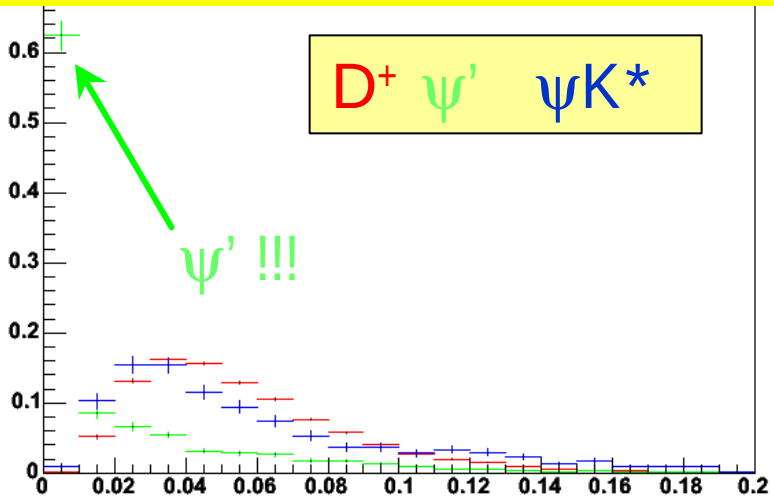




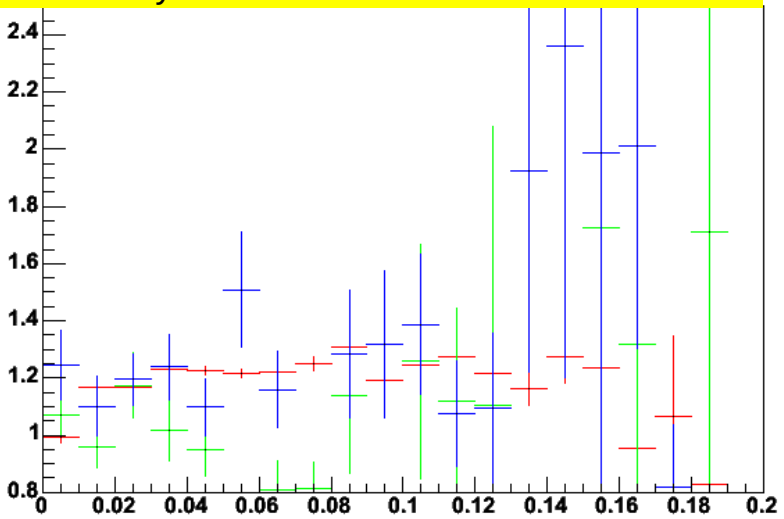
- Comparing ψ' to average of other samples in each bin
- Everything excluded except ct
- Why? I can think of possible reasons, but in terms of bugs mostly! WORK IN PROGRESS

Ct and L_{xy}

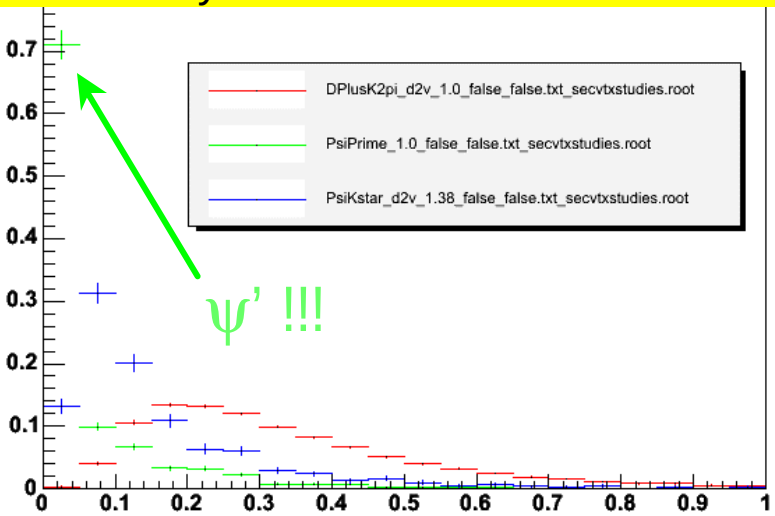
Ct(one) distribution



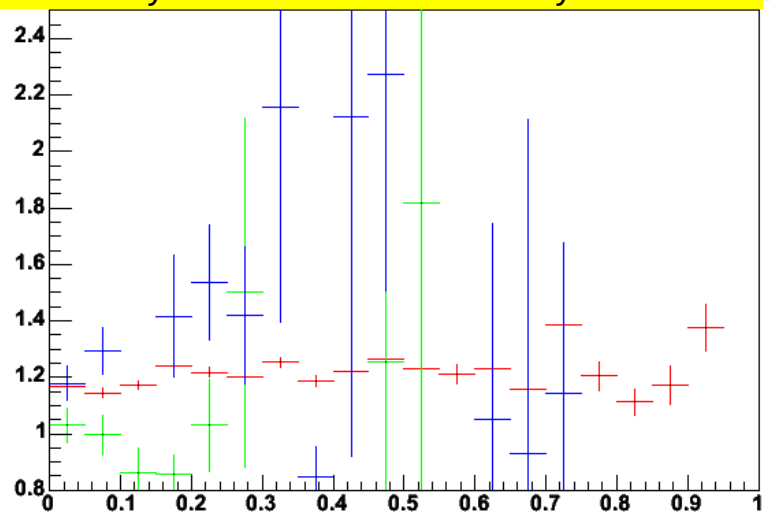
L_{xy}(two) pulls vs ct(B)



L_{xy} distribution



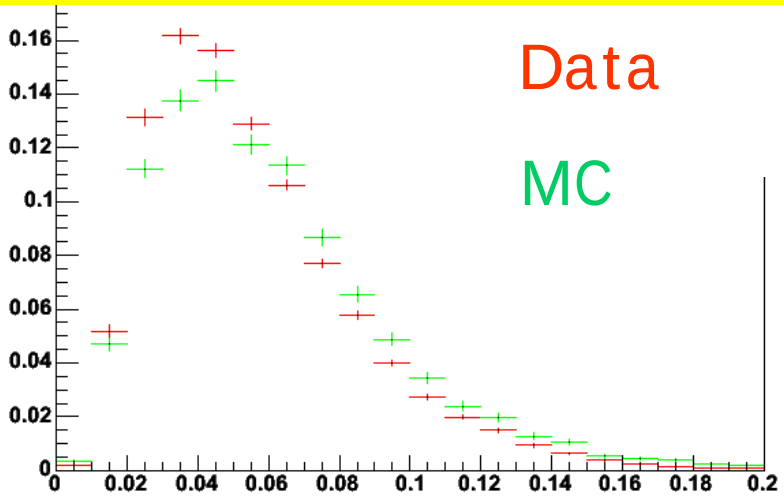
L_{xy}(two) pulls vs L_{xy}(B)



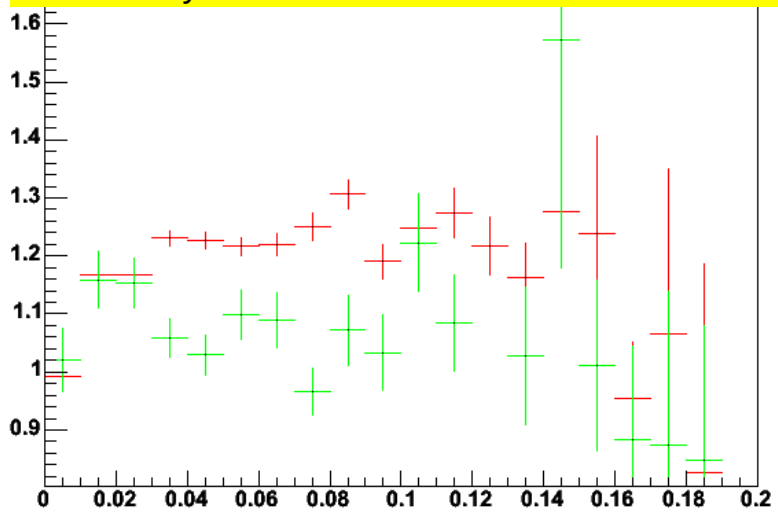
The problem does not show up with prompt objects!

D^+ Montecarlo vs data

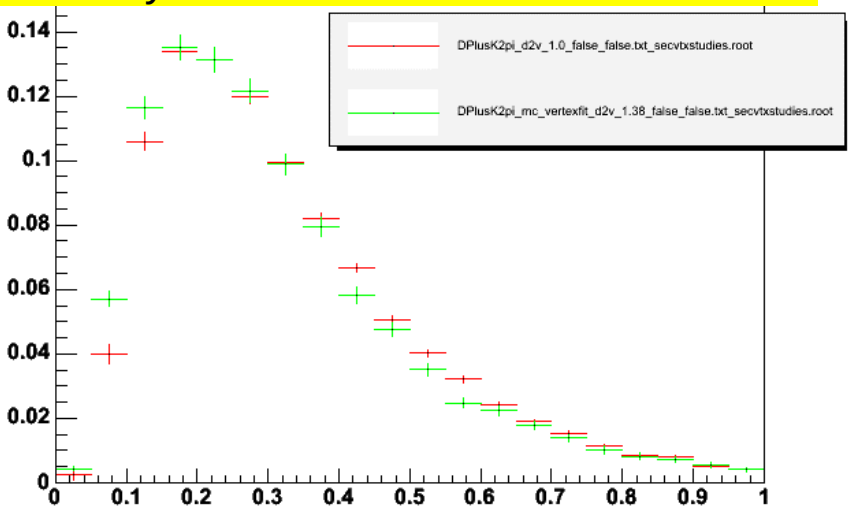
Ct(one) distribution



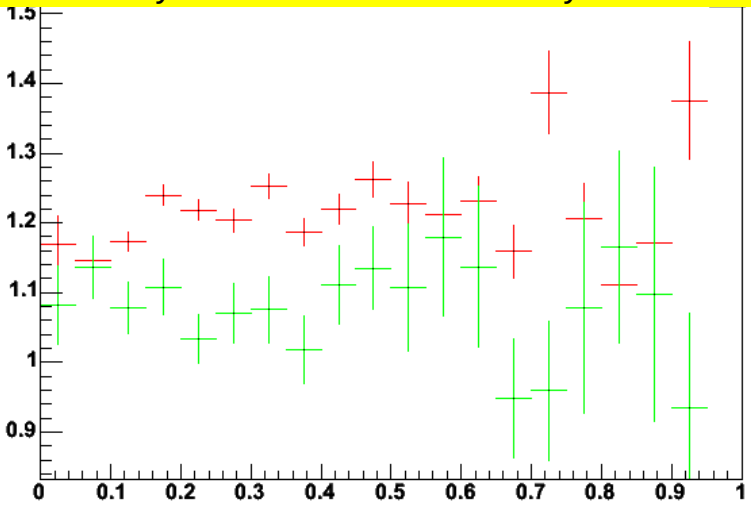
L_{xy}(two) pulls vs ct(B)



L_{xy}(one) distribution



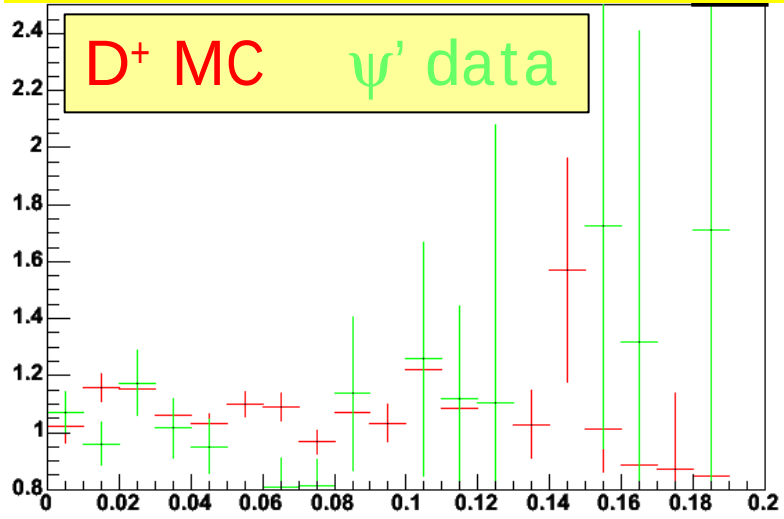
L_{xy}(two) pulls vs L_{xy}(B)



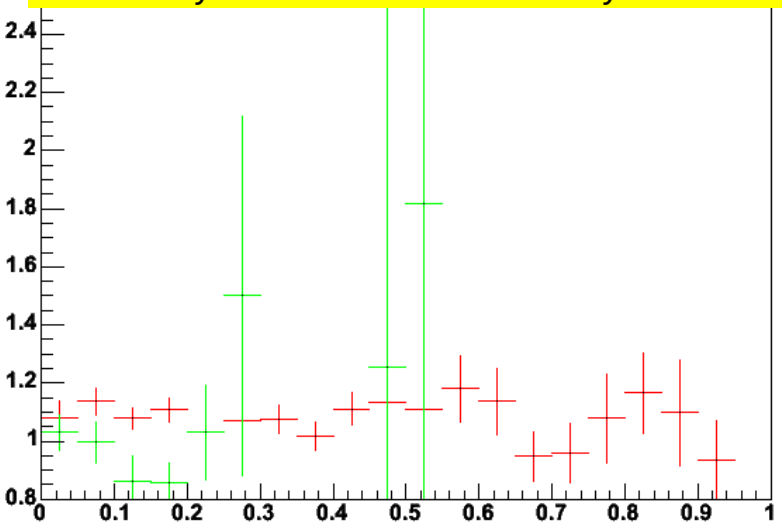
The problem does not show up in montecarlo!

ψ' data vs D^+ MC

L_{xy}(two) pulls vs ct(B)



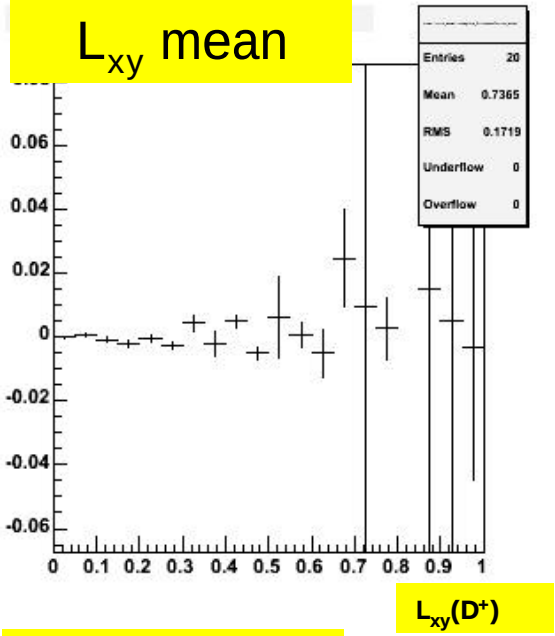
L_{xy}(two) pulls vs L_{xy}(B)



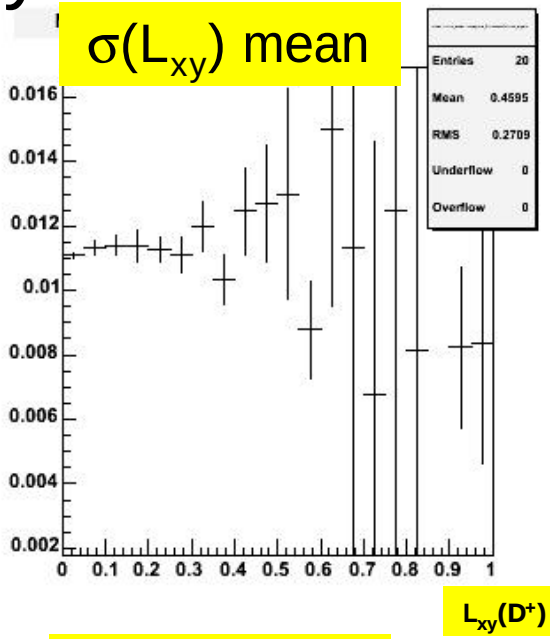
- They are much more similar!
- The 'bug' affects non-prompt data only!!!

L_{xy} $\sigma(L_{xy})$ and pulls for ψ'

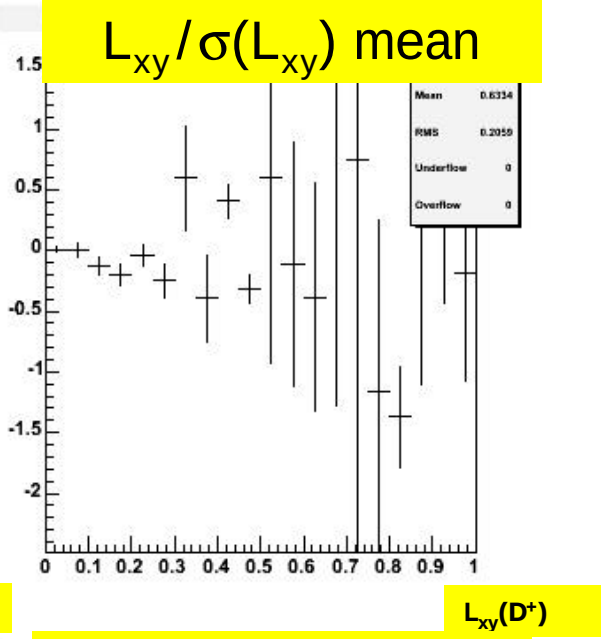
L_{xy} mean



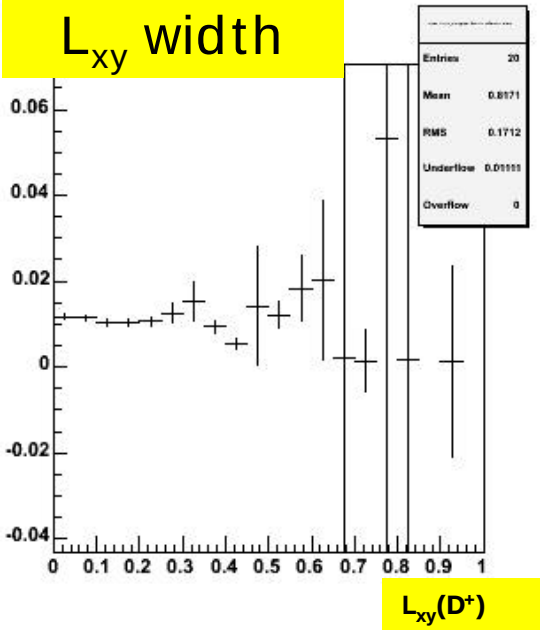
$\sigma(L_{xy})$ mean



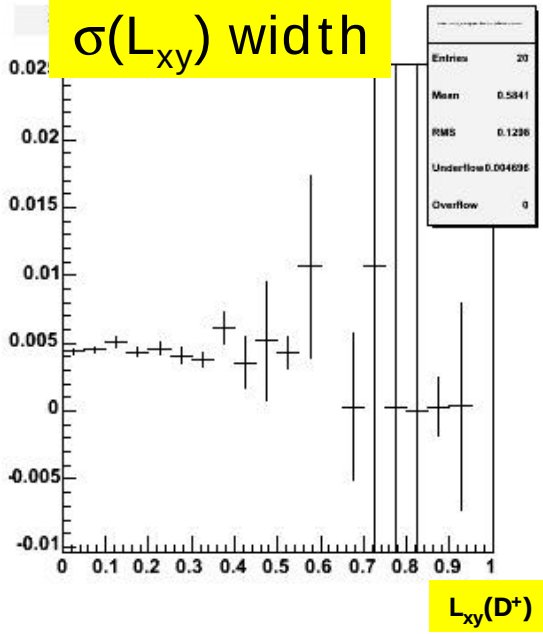
$L_{xy}/\sigma(L_{xy})$ mean



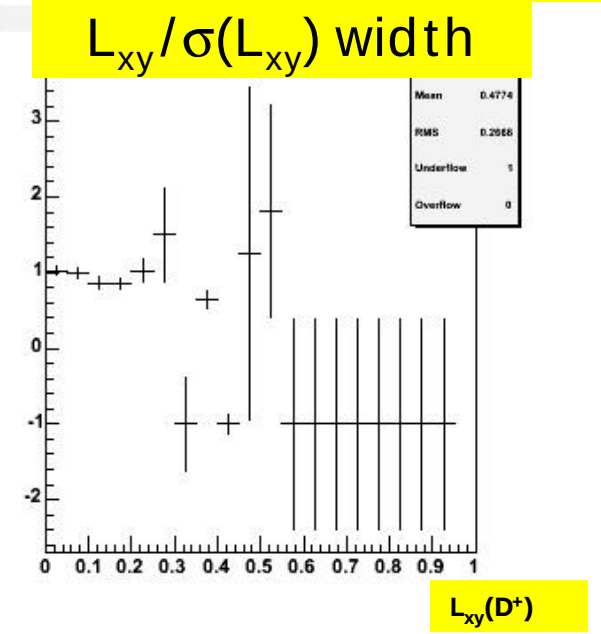
L_{xy} width



$\sigma(L_{xy})$ width



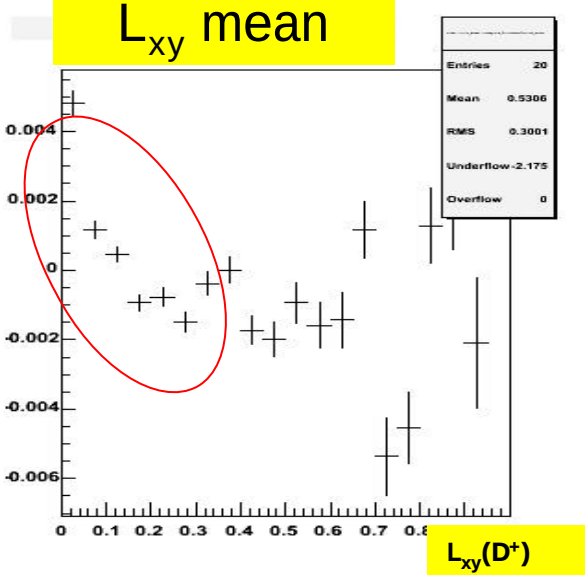
$L_{xy}/\sigma(L_{xy})$ width



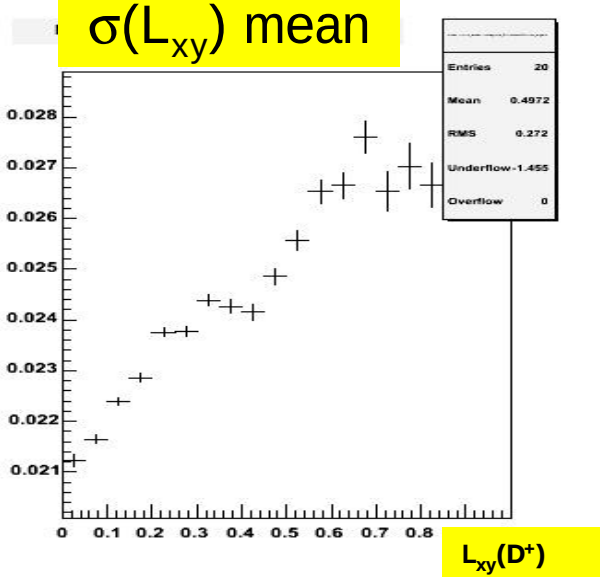
Same plots in D^+ data:

Is it in $\sigma(L_{xy})$ or in L_{xy}?

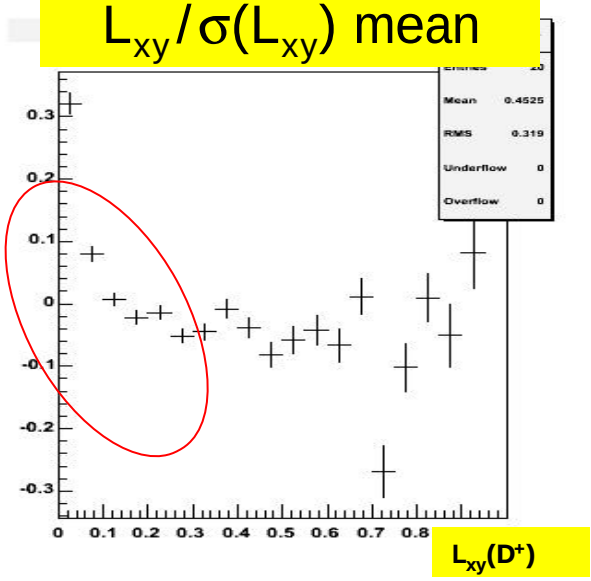
L_{xy} mean



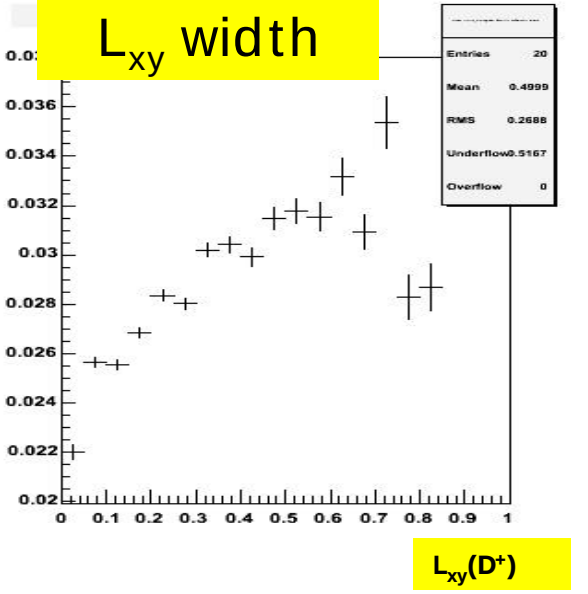
$\sigma(L_{xy})$ mean



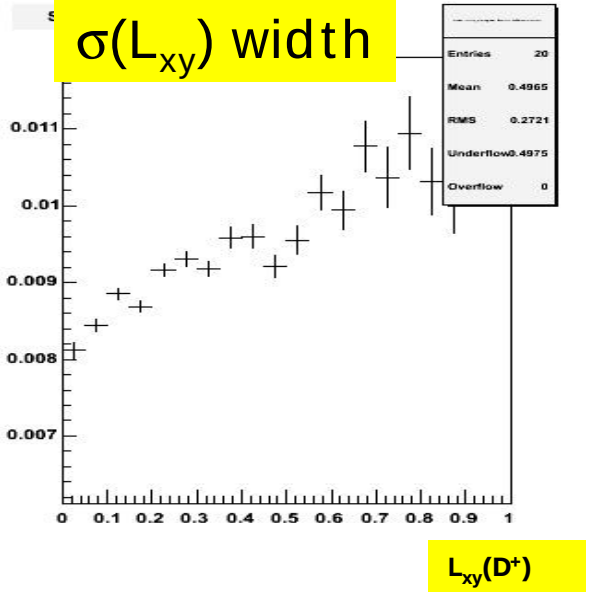
$L_{xy}/\sigma(L_{xy})$ mean



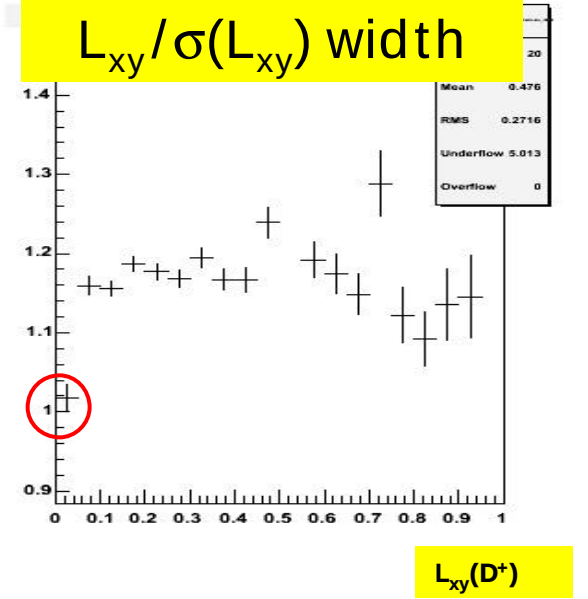
L_{xy} width



$\sigma(L_{xy})$ width

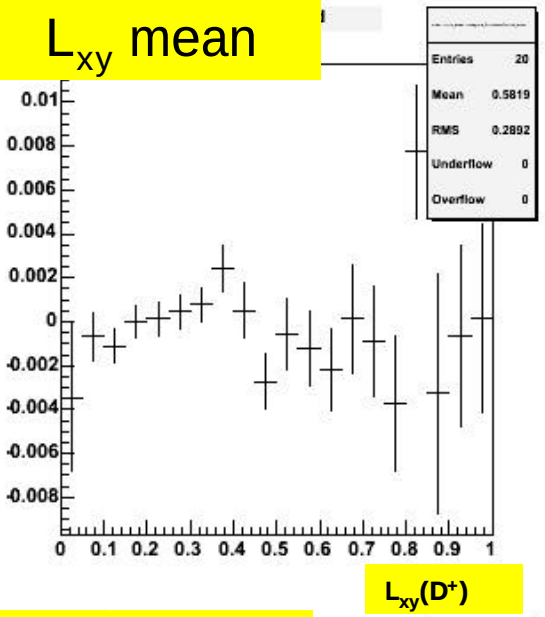


$L_{xy}/\sigma(L_{xy})$ width

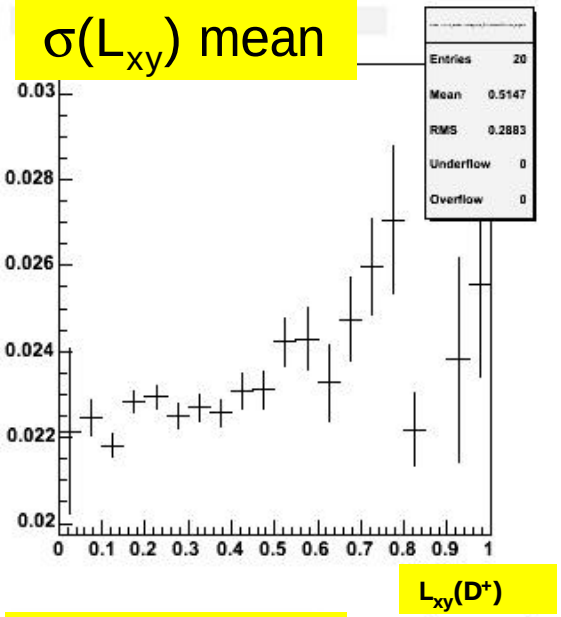


Same plots for MC D^+

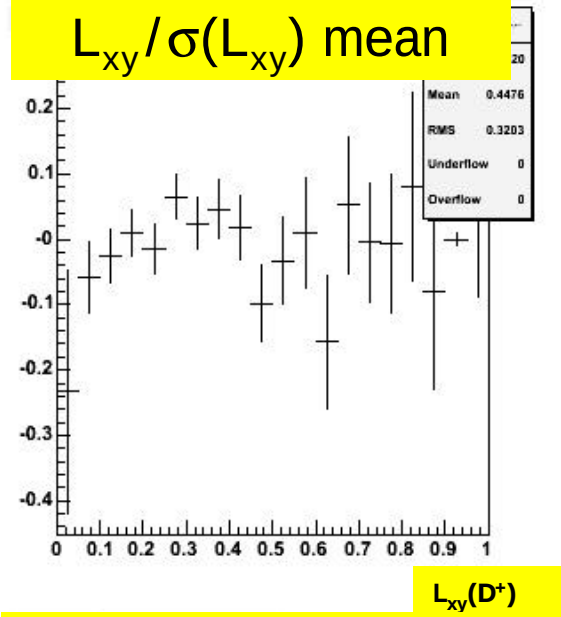
L_{xy} mean



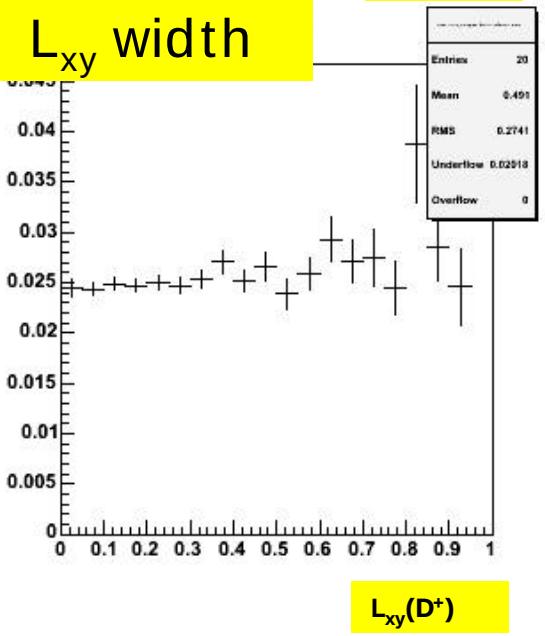
$\sigma(L_{xy})$ mean



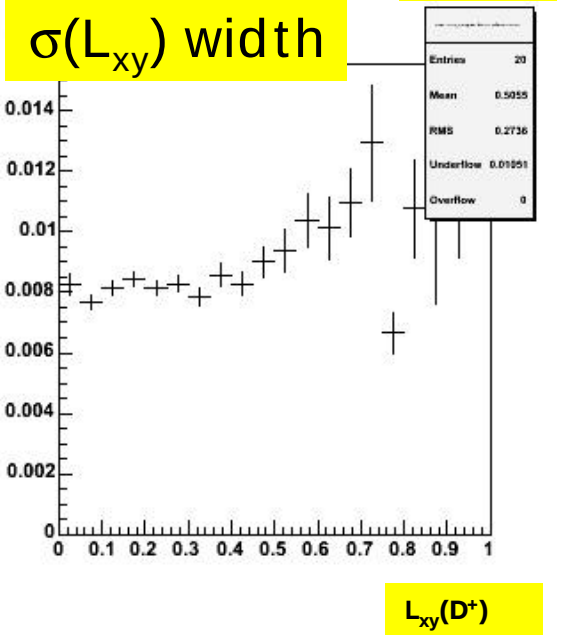
$L_{xy}/\sigma(L_{xy})$ mean



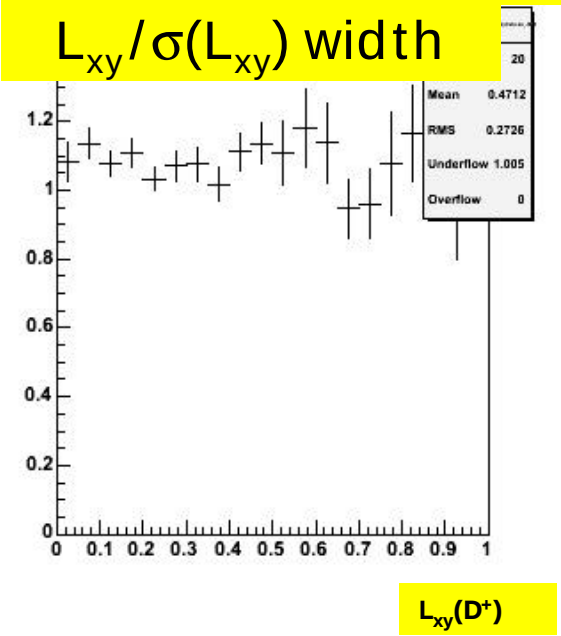
L_{xy} width



$\sigma(L_{xy})$ width

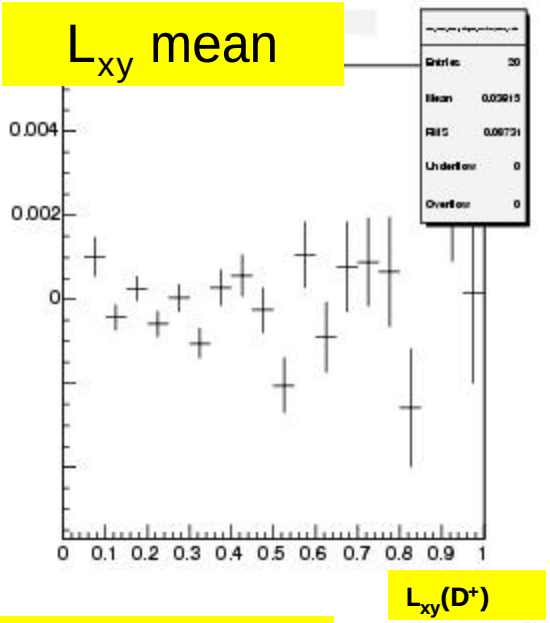


$L_{xy}/\sigma(L_{xy})$ width



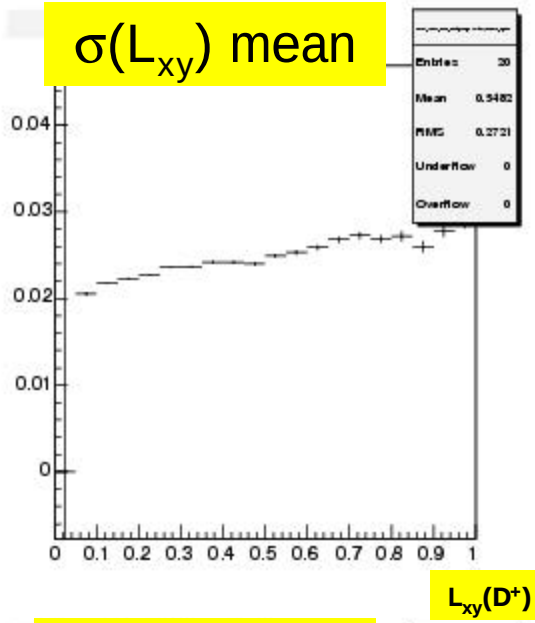
Same plots for D^+ without L_{00}

L_{xy} mean



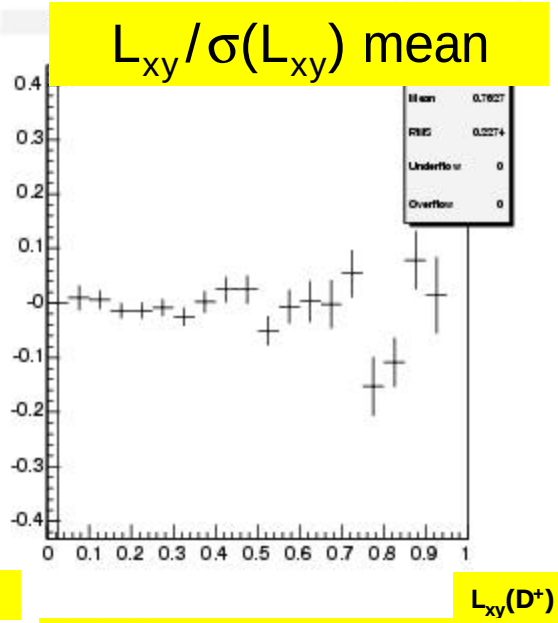
$L_{xy}(D^+)$

$\sigma(L_{xy})$ mean



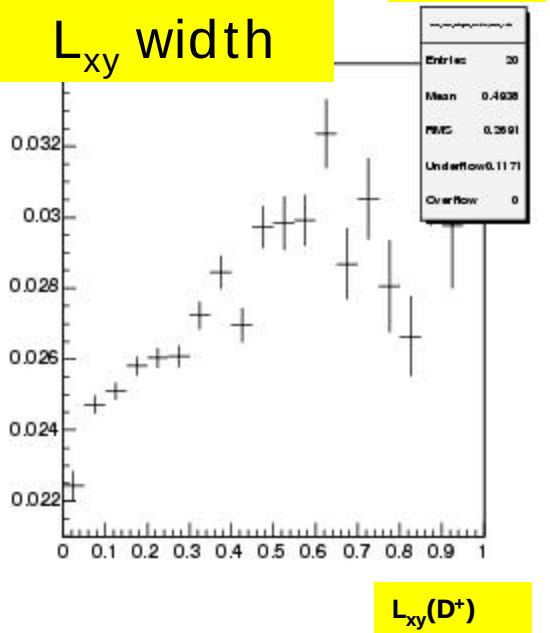
$L_{xy}(D^+)$

$L_{xy}/\sigma(L_{xy})$ mean



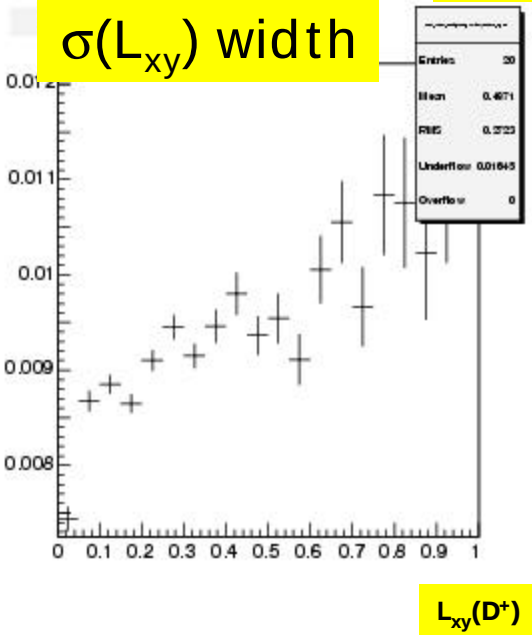
$L_{xy}(D^+)$

L_{xy} width



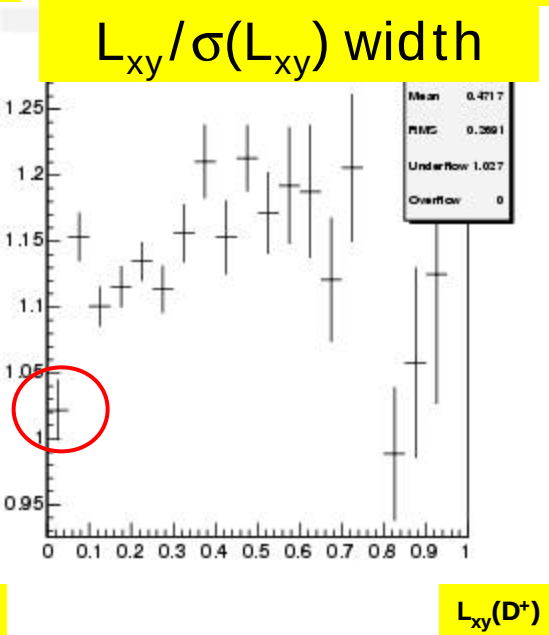
$L_{xy}(D^+)$

$\sigma(L_{xy})$ width



$L_{xy}(D^+)$

$L_{xy}/\sigma(L_{xy})$ width



$L_{xy}(D^+)$

Secondary Vertex Conclusions, so far

- Surprising Dependency on ct
  - Problem shows up 'only' in long lived signal in data
  - it's a pity that's what we want to use for our analyses ;)
  - Semileptonic lifetime? (biases are present as well!)
- Working on finding the cause
  - ✓ Montecarlo: It works!
  - ✓ Swimming of track's covariance to the vertex (CTVMFT does not account for that): no effect
  - o Investigate other variables in data (Impact parameter?)
  - Probe other samples (D^0?)
  - The problem I see is consistent with Aart's findings on the impact parameter scale factor as a function of $\Delta\phi(K\pi\text{-}\pi)$
- This is the last pending big issue at the moment

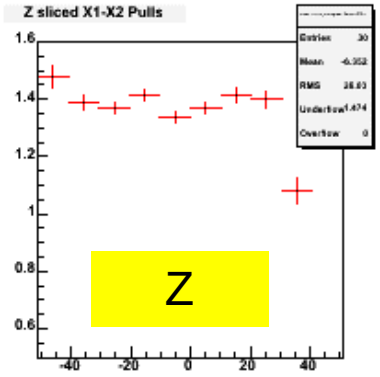
Moving along the plans for improvements!

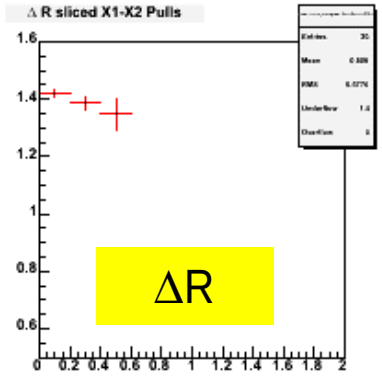
1. Understand beamline parameterization:
   I. Is it modeled correctly
   II. Is it measured correctly
   $\Rightarrow$ Include our best knowledge of it!
2. Are secondary vertex pulls ok?
   I. Check with montecarlo truth
   II. Use n-prong vertices ($J/\psi K$, $K\pi\pi^{+/0}$, $K\pi\pi\pi^{+/0}$)
3. Investigate dependencies (Pt, z,multiplicity, η) with full statistics

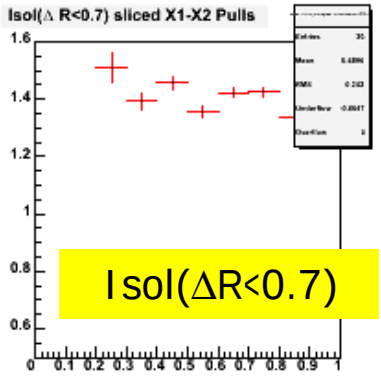
Plan

- PV shows a very consistent picture
- Finish up PV studies (~days):
  - re-run some ntuples to get full statistics in all cases
  - Including $K\pi\pi\pi$, $D\pi\pi\pi$
  - Use also $B\rightarrow\psi K$ background to get a source of studies for prompt L_{xy} pulls?
- SV riddle to be solved!
- I am working full steam on this.
- One more weeks according to schedule, to straighten everything out, document and insert in the blessing pipeline.

Plots a la 7500

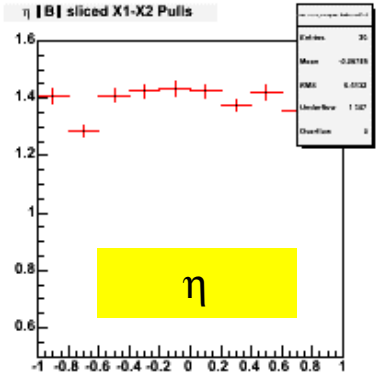


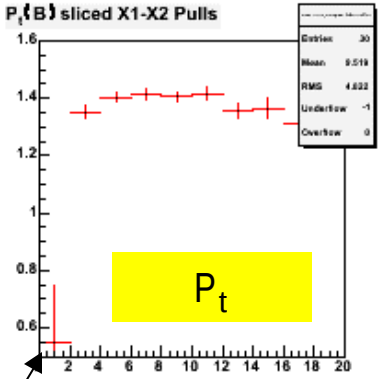




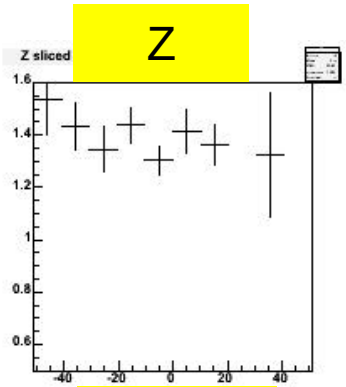
Primary Vertex Pulls for:

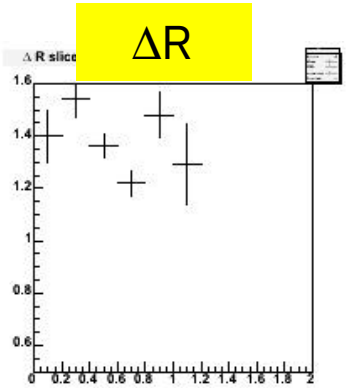
- All B signals (left)
- ψ' (below)

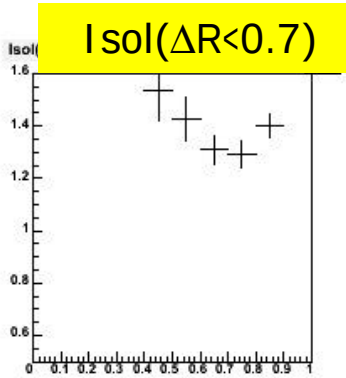


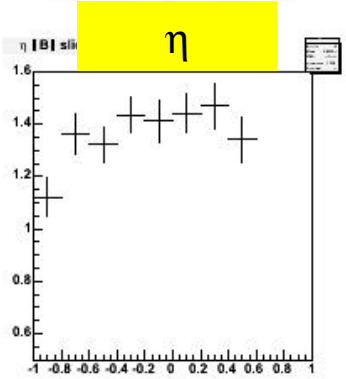


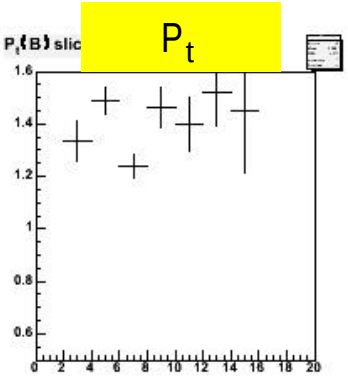
Just no statistics!



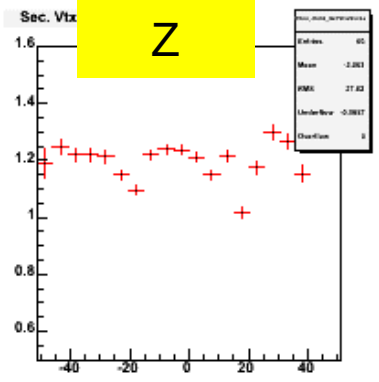


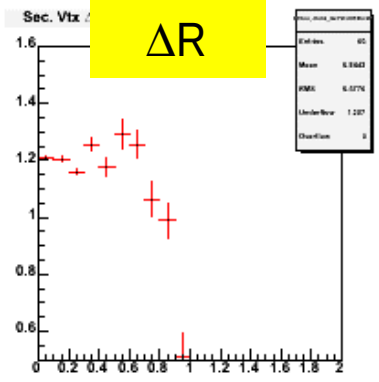


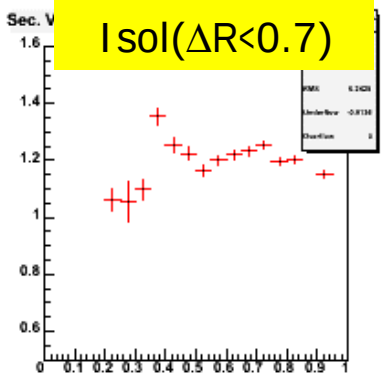


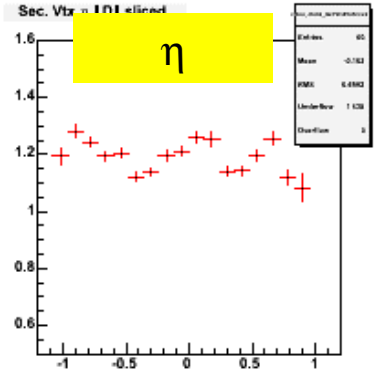


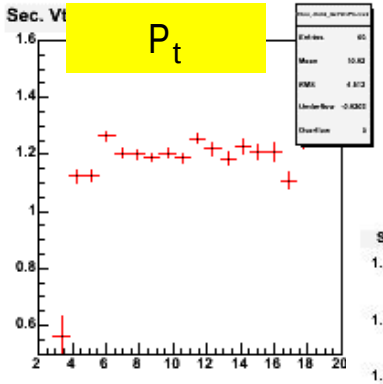
Non-statistical fluctuations dominated by fit model!





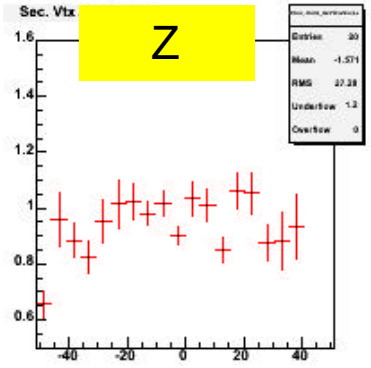


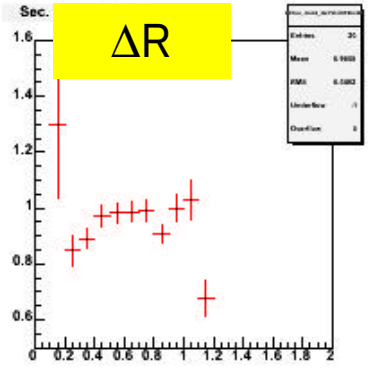


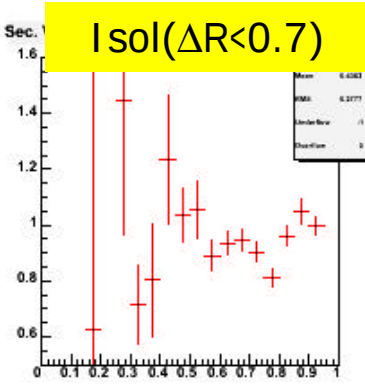


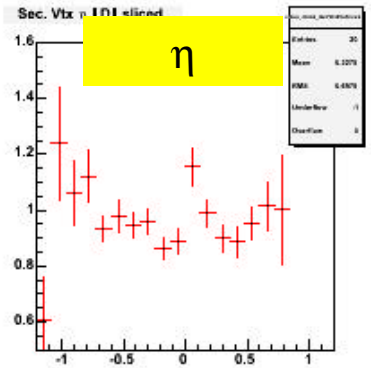
Secondary Vertex Pulls for:

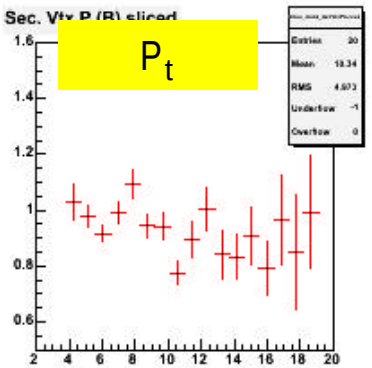
- All B signals (left)
- ψ' (below)











All ψ' have pulls of ~1, all the B have pulls of ~1.2.. There seems to be no significant dependence except from ct!!!

Backup

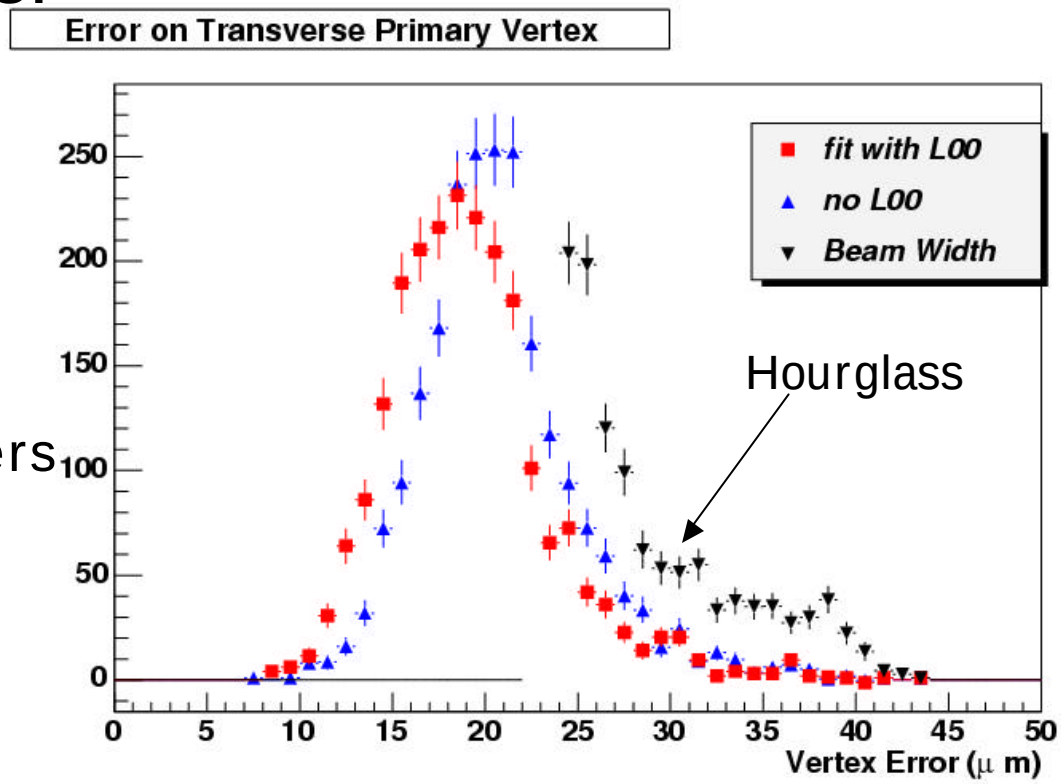
Outline

- Current status
  - What was used for the mixing results
  - What is the current understanding of Ebe
- Plans for improvements
  - How can we improve?

Current status

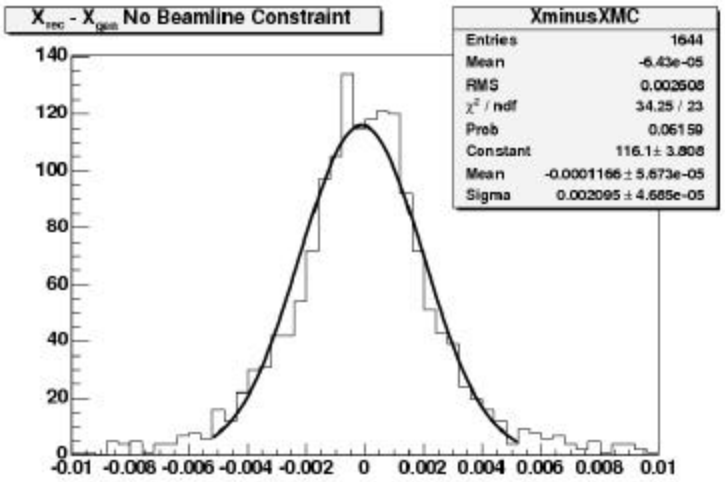
EbE: itearative track selection/pruning algorithm to provide an unbiased estimate of the PV position on an Event-by-Event basis

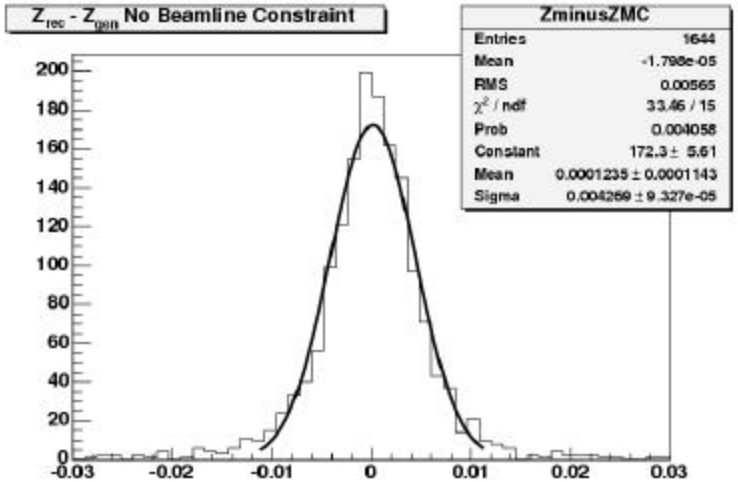
- Hadronic analyses used a flat ~25um beamline!
- Possible improvements:
  - Move to “hourglass”
  - Move to EbE
  - EbE + Hourglass
    - One of the ½ leptonic analyses used this with fixed hourglass parameters



What do we know about EbE?

- Unbiased estimator of PVTX





Reasonable (~5%) control of systematics

Mode	x scale	y scale	z scale
$B^{\pm} \to \psi K^{\pm}$	1.327 ± 0.035	1.399 ± 0.035	1.375 ± 0.029
$B^{\pm} \to D^0 \pi^{\pm}$	1.408 ± 0.030	1.398 ± 0.031	1.367 ± 0.29
$B^0 \to D^{\pm} \pi^{\mp}$	1.426 ± 0.034	1.336 ± 0.029	1.288 ± 0.027

	Transverse	**Z**
Data (V_1-V_2)	1.33±0.035	1.37±0.035
MC (V_1-V_2)	1.192±0.034	1.26±0.035
MC (V-truth)	1.24±0.036	1.23±0.032
J/ψ Prompt Peak	1.236±0.024	~ND~
J/ψ d_0/s	1.176±0.019	~ND~

Cross checks using I.P.(B)

Pull on Impact Parameter

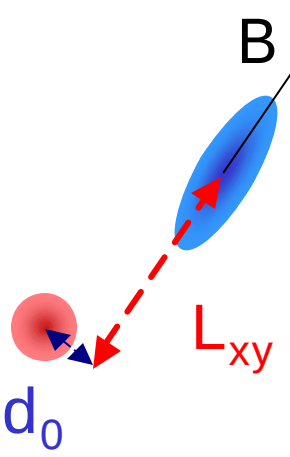
Mode	Beamline $\sigma = 25\mu$	Beamline z dependent σ	Event-by-Event w/beam constraint	Event-by-Event w/o beam constraint
$B^{\pm} \to D^0\pi^{\pm}$	1.297 ± 0.025	1.178 ± 0.039	1.202 ± 0.021	1.050 ± 0.025
$B^0 \to D^{\pm}\pi^{\mp}$	1.256 ± 0.026	1.118 ± 0.027	1.163 ± 0.020	1.046 ± 0.027

Z dep. Beamline improves pulls!

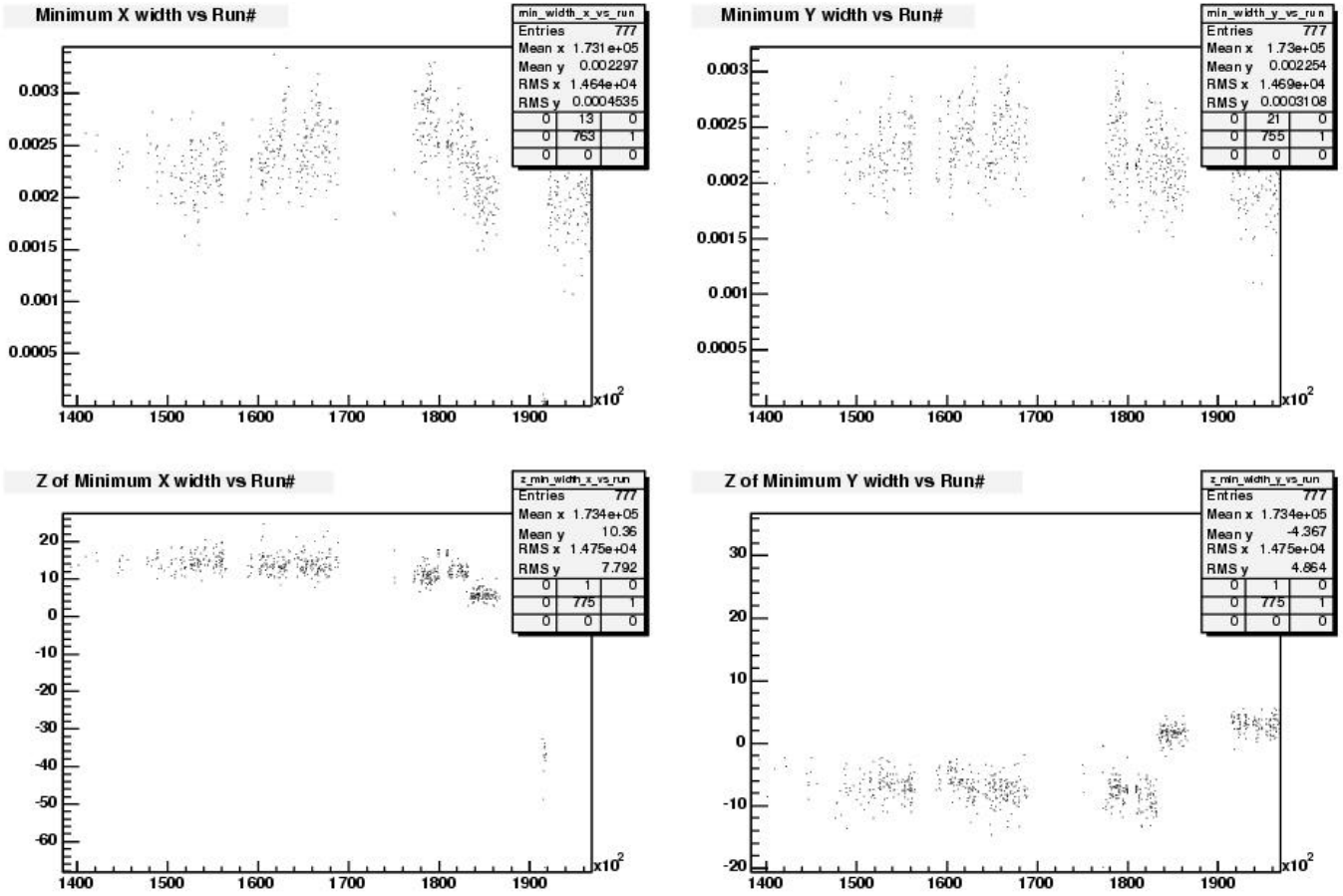
Something funny when beamline is used!

Scale factors work!

- L_{xy} involves three ingredients:
  - EbE
  - Secondary vertex
  - Beamline (in beamline constrained fits)



Time dependence of Hourglass parameters

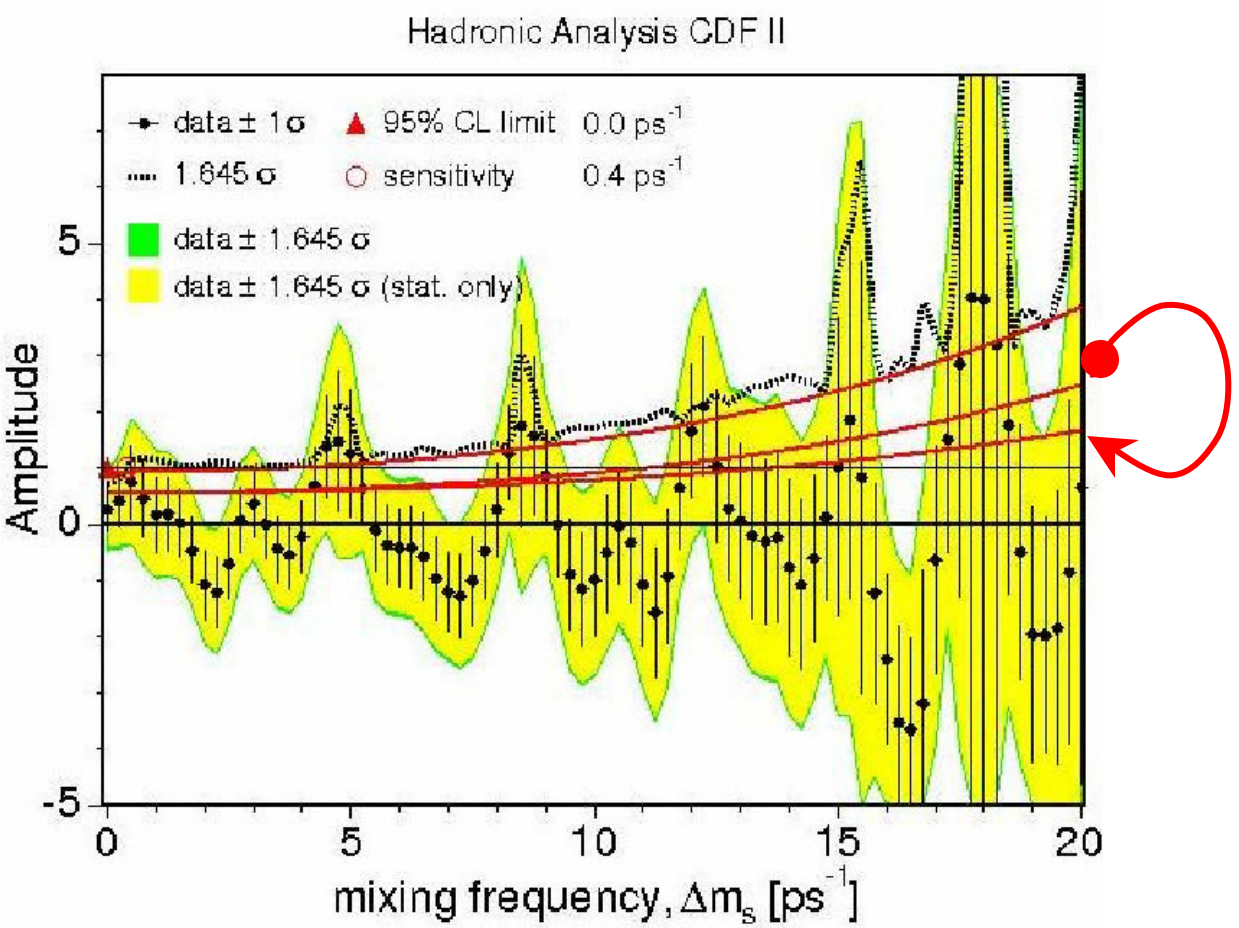


Implementing DB access of time-dependent parameters

What do we gain?

Euphemism

1. 15-20% In vertex resolution!
2. Better control of systematics (hard to evaluate)
3. Correct EbE resolution (it is not clear that it is correct now)



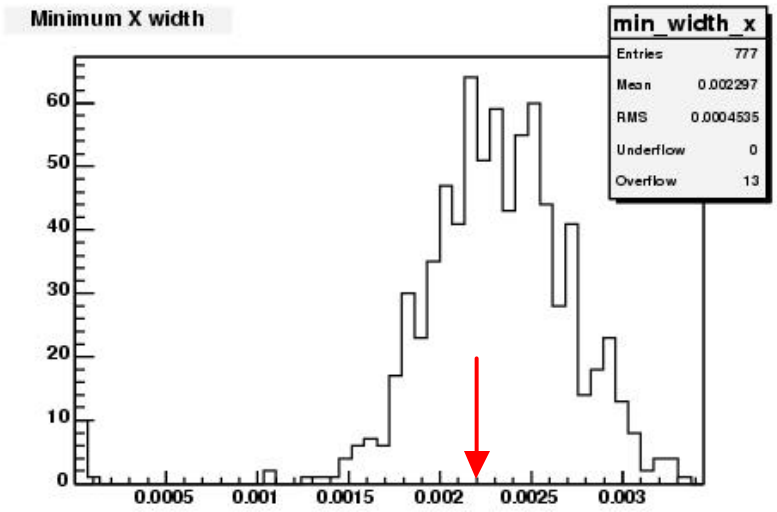
- Red arrow is the effect of 1. Only
- Point 2. Affects mostly the green area (tiny ?)
- Point 3. Has an effect qualitatively similar to 1., but hard to evaluate

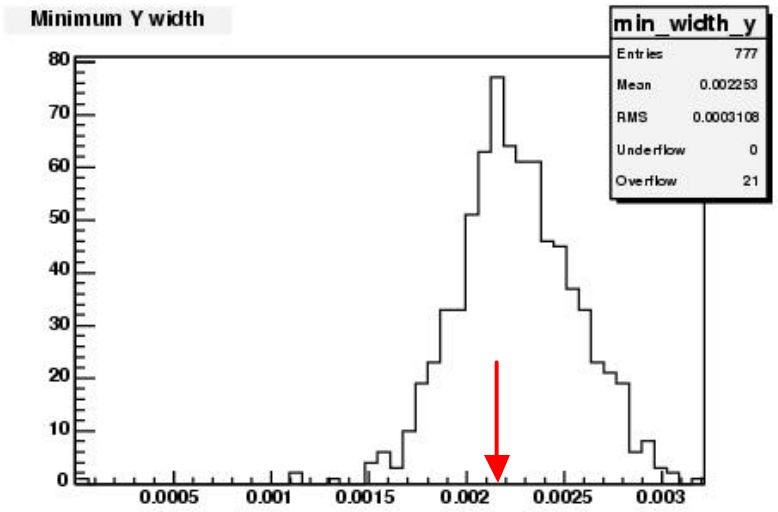
Hadronic analysis systematics

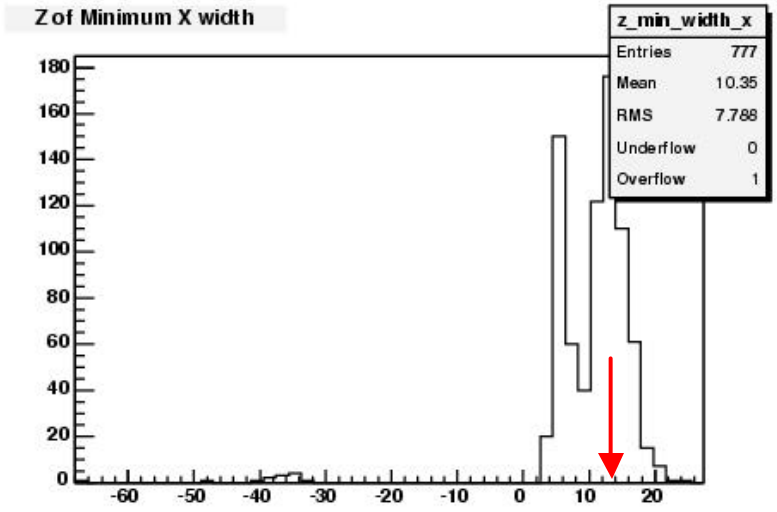
source	selected Δm_s scan points				
	0.0	5.0	10.0	15.0	20.0
$B_s \to D_s K$ level	0.019	0.024	0.030	0.037	0.047
dilution scale factors	0.143	0.168	0.205	0.254	0.314
dilution templates	0.119	0.147	0.178	0.211	0.246
fraction of Λ_b	0.014	0.009	0.009	0.011	0.012
Punzi term for σ_{ct}	0.009	0.008	0.022	0.033	0.030
dilution of $B \to DX$	0.025	0.001	0.000	0.000	0.001
σ_{ct} scale factor	0.000	0.024	0.061	0.090	0.144
usage of L00 in bias curve	0.001	0.001	0.001	0.001	0.001
Bs lifetime uncertainty	0.001	0.001	0.001	0.001	0.001
reweighted p_t spectrum	0.001	0.001	0.001	0.001	0.001
non-Gaussian tails in ct resol.	0.001	0.027	0.052	0.078	0.104
neglect B^0 in fit	0.039	0.036	0.033	0.031	0.028
effect of $\Delta\Gamma/\Gamma = 0.2$	0.028	0.028	0.028	0.028	0.028
Total systematic	0.195	0.232	0.289	0.357	0.443
Statistical	0.393	1.129	1.010	2.652	5.281

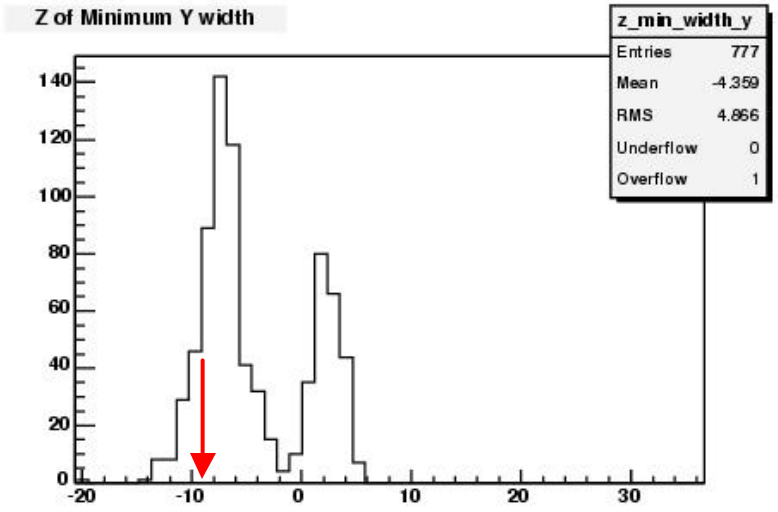
Hourglass parameters from DB

Profiles









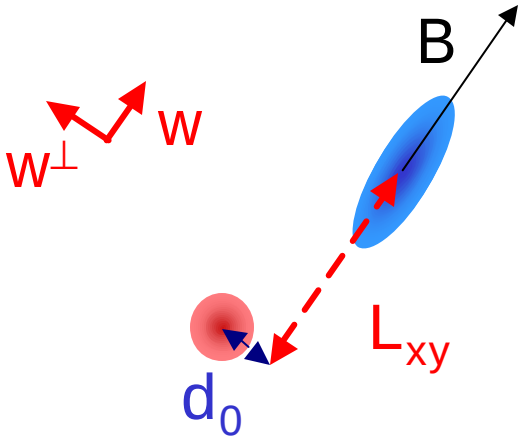
Relative PV/BV contribution to d_0 and L_{xy} pulls

$$s^2_{L_{xy}} = {}^t w s^2_{PV} w + {}^t w s^2_{SV} w$$

$$s^2_{d_0} = {}^t w^\perp s^2_{PV} w^\perp + {}^t w^\perp s^2_{SV} w^\perp$$

$$w = (x, y)$$

$$w^\perp = (y, -x)$$



- PV and BV are linear combinations of the same covariances (σ_{PV}, σ_{SV}), with different coefficients
- L_{xy} sensitive to the major axis of σ_{SV}
- Relative weight of PV and SV covariances different for L_{xy} and d_0
- Look at:

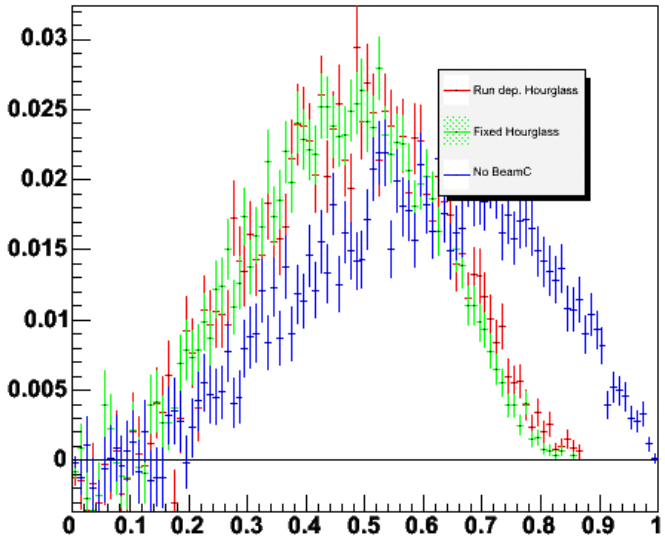
$$\sqrt{\frac{{}^t w s^2_{PV} w}{s^2_{L_{xy}}}} \quad \sqrt{\frac{{}^t w^\perp s^2_{PV} w^\perp}{s^2_{d_0}}}$$

$$\sqrt{\frac{{}^t w s^2_{SV} w}{s^2_{L_{xy}}}} \quad \sqrt{\frac{{}^t w^\perp s^2_{SV} w^\perp}{s^2_{d_0}}}$$

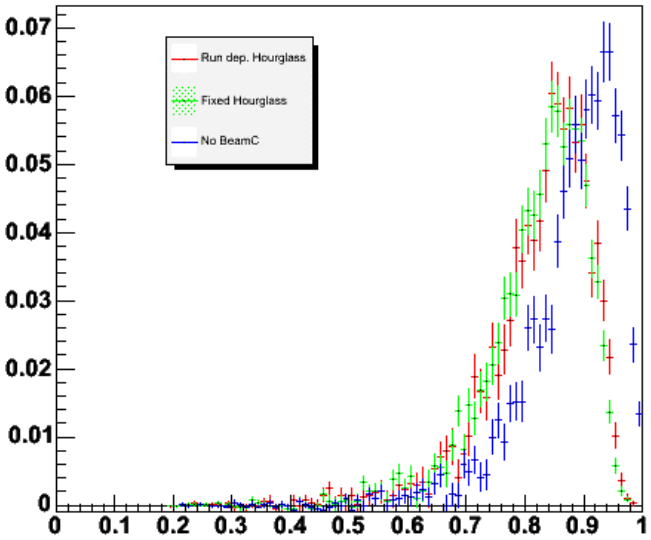
Note: the two L_{xy} (or d_0) pieces do not linearly add to 1!

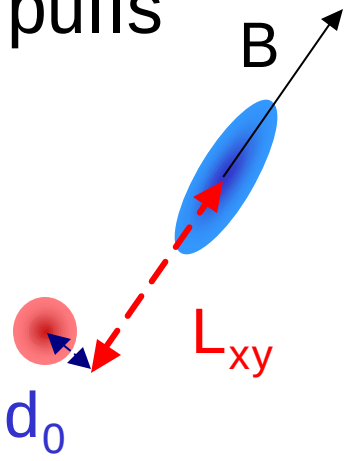
Relative PV/BV contribution to IP and Lxy pulls

PV contribution to the L_{xy} error



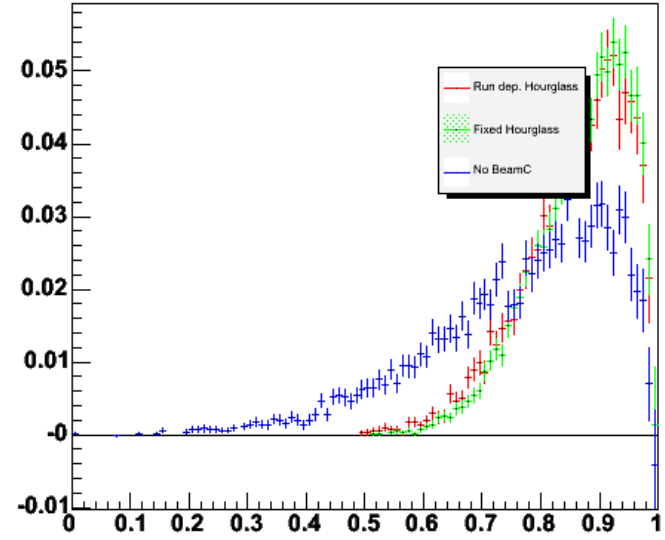
PV contribution to the d_0 error



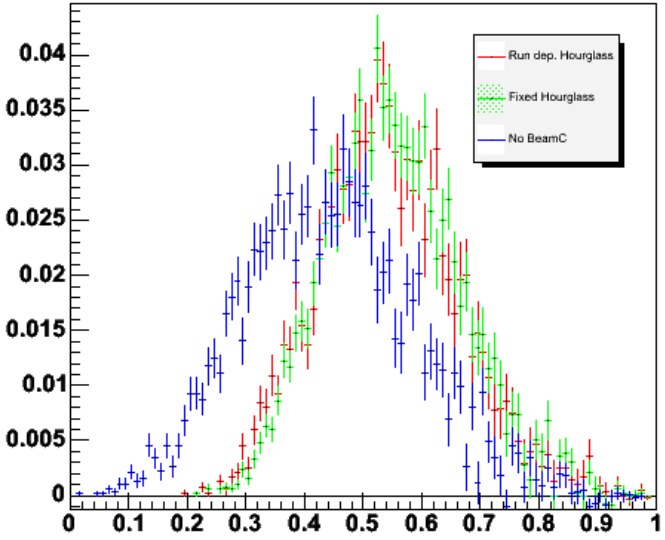


- Not Beam Constrained
- Beam constrained
- Beam constrained with run-dep. hourglass

SV contribution to the L_{xy} error



SV contribution to the d_0 error



ψK

ψK^+

ψK^*

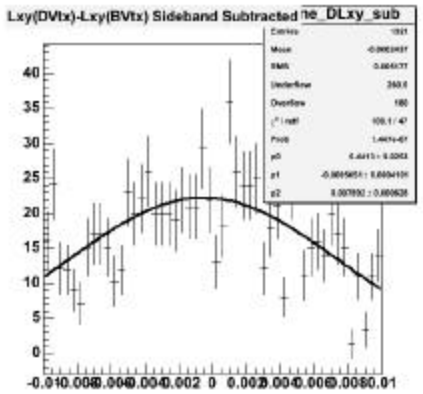
Lxy(2)

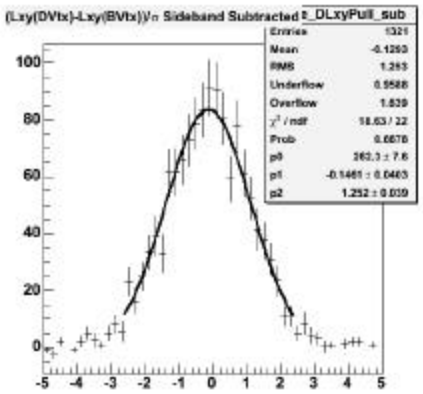
Pull

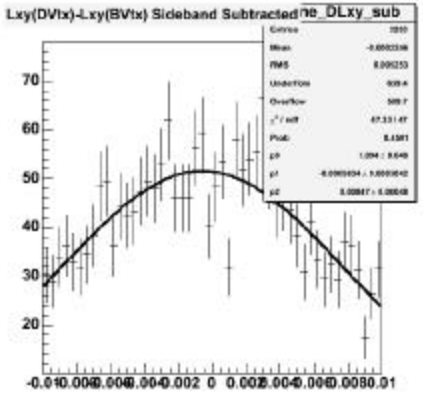
Lxy(2)

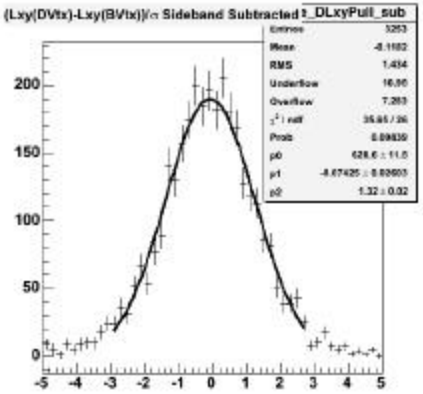
Pull

One Gaussian

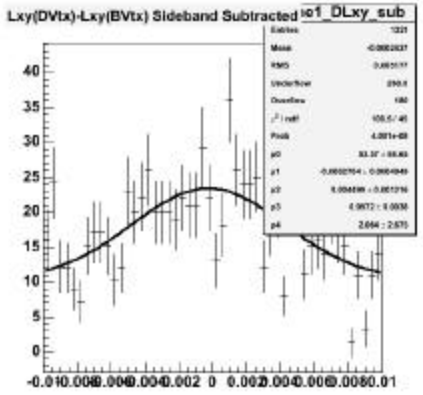


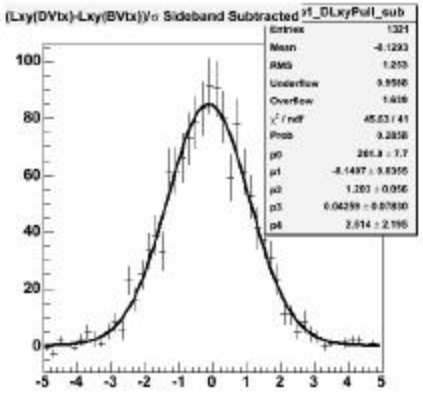


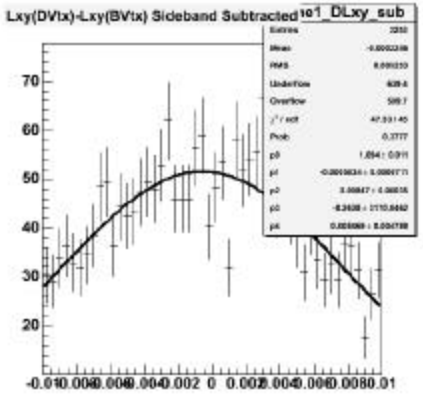


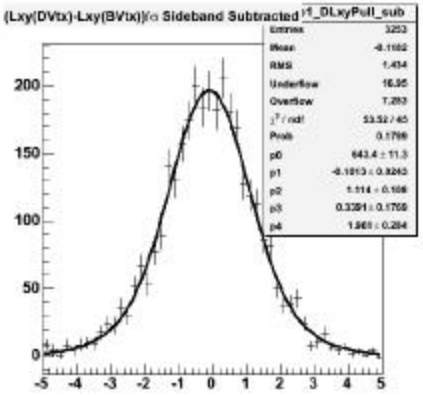


Two gauss.









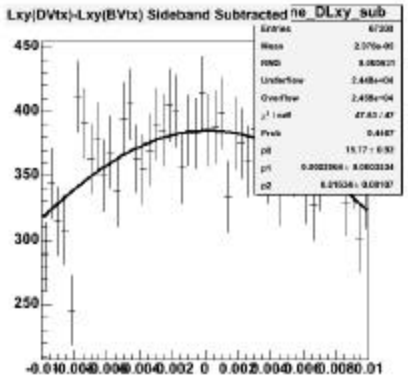
Charm…

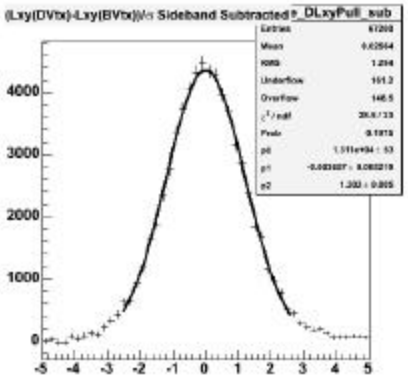
D^+

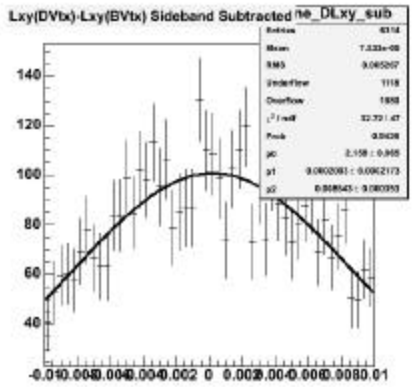
$\psi' \rightarrow \psi\pi\pi$ "3-1"

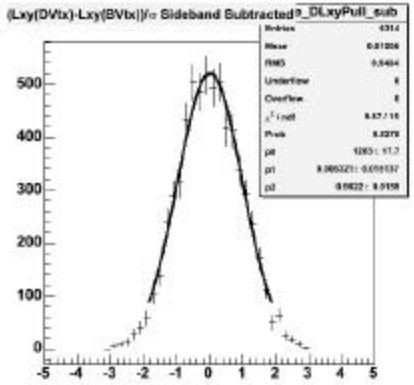
Lxy(2) | Pull | Lxy(2) | Pull

One Gaussian

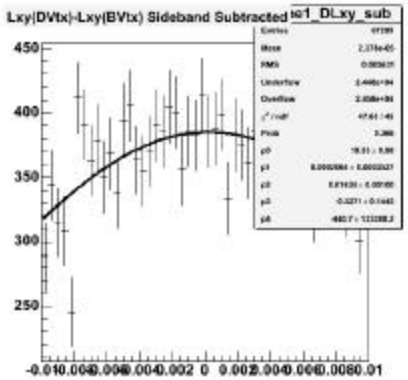


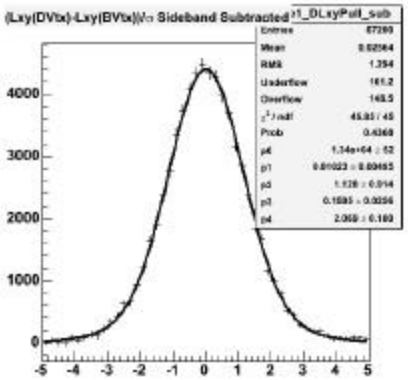


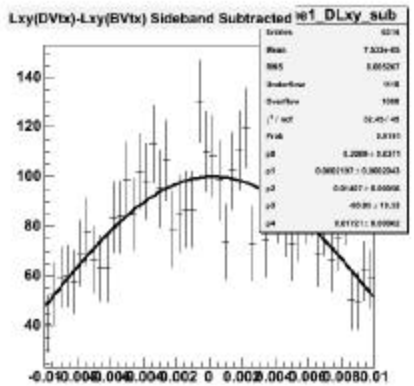


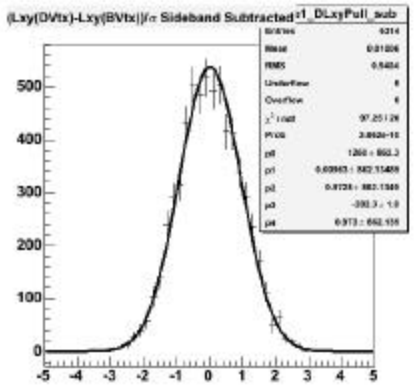


Two gauss.



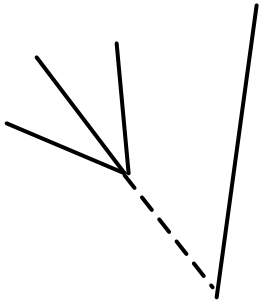




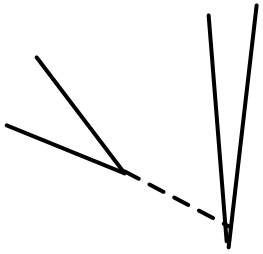


ψ' can be used in two different ways to probe SV

"3-1"



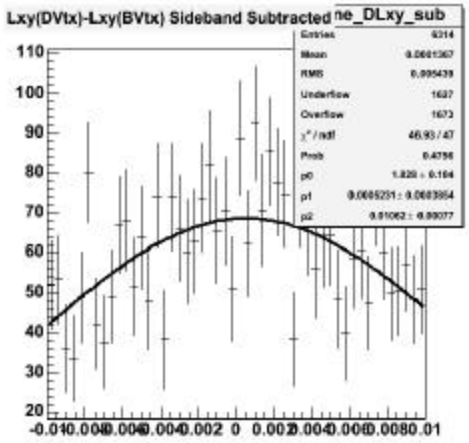
"2-2"

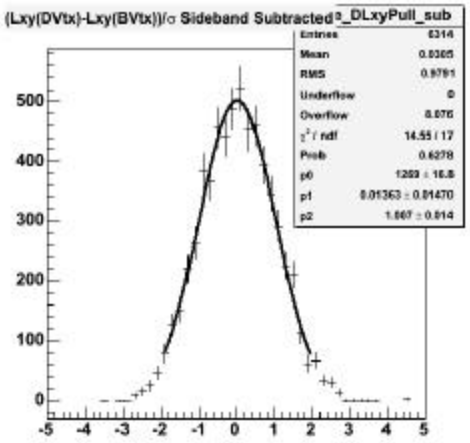


$\psi' \rightarrow \psi\pi\pi$ "2-2"

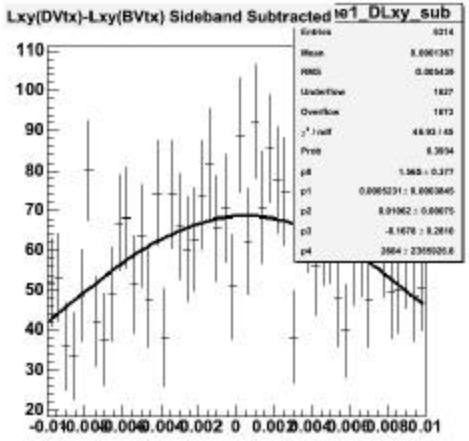
Lxy(2) Pull

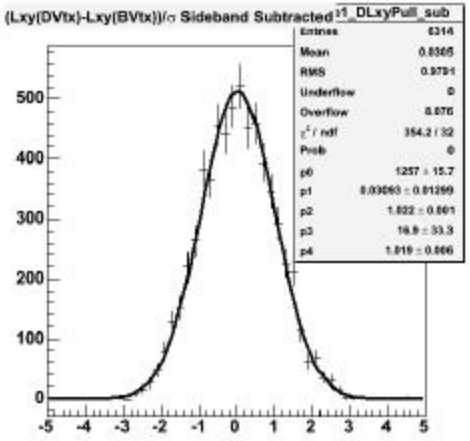
One Gaussian





Two gauss.





Bottomline:

- SV and PV enter very differently in L_{xy} and d_0
- Relative contribution depends strongly on PV and SV scales
- Beam constraint squeezes the PV resolution significantly. Becomes second order on L_{xy}!
- We are in a regime where the SV scale factor is critical!

… now let's get more quantitative!