EbE Vertexing for Mixing
Update (CDF-7673)

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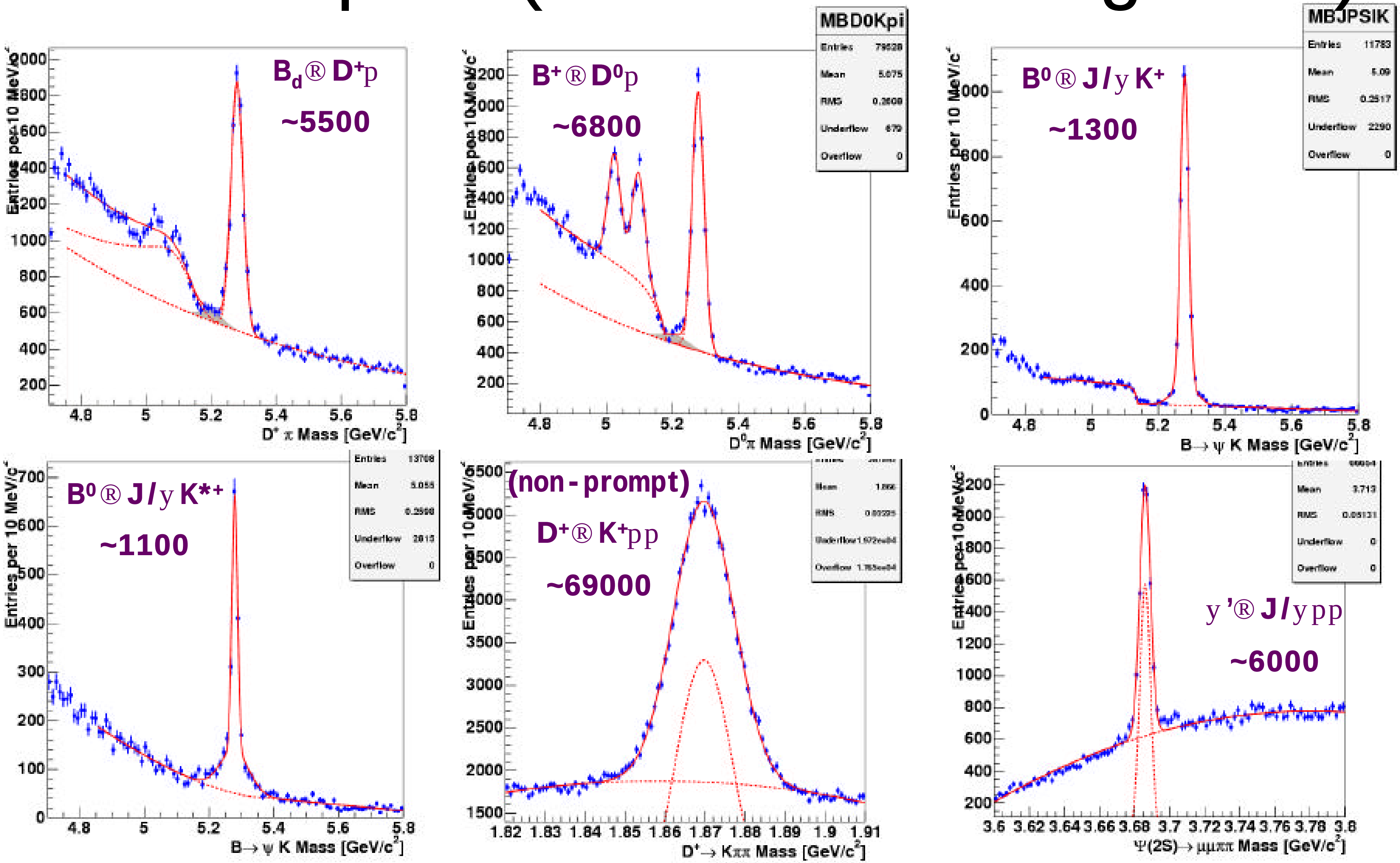
Why our yields are lower when compared with other analyses on the same samples?

- Short answer: fixed
- Long answer: most this talk

Two cuts mostly responsible:

- χ^2_{fit} was rather tight (χ^2_{3D}<10-15 in most cases)
- Mass histograms were filled with pretty tight requirements on the Primary Vertex:
  - $\exists$ of at least two PV (for V_1-V_2)
- Various other cuts were tighter than necessary

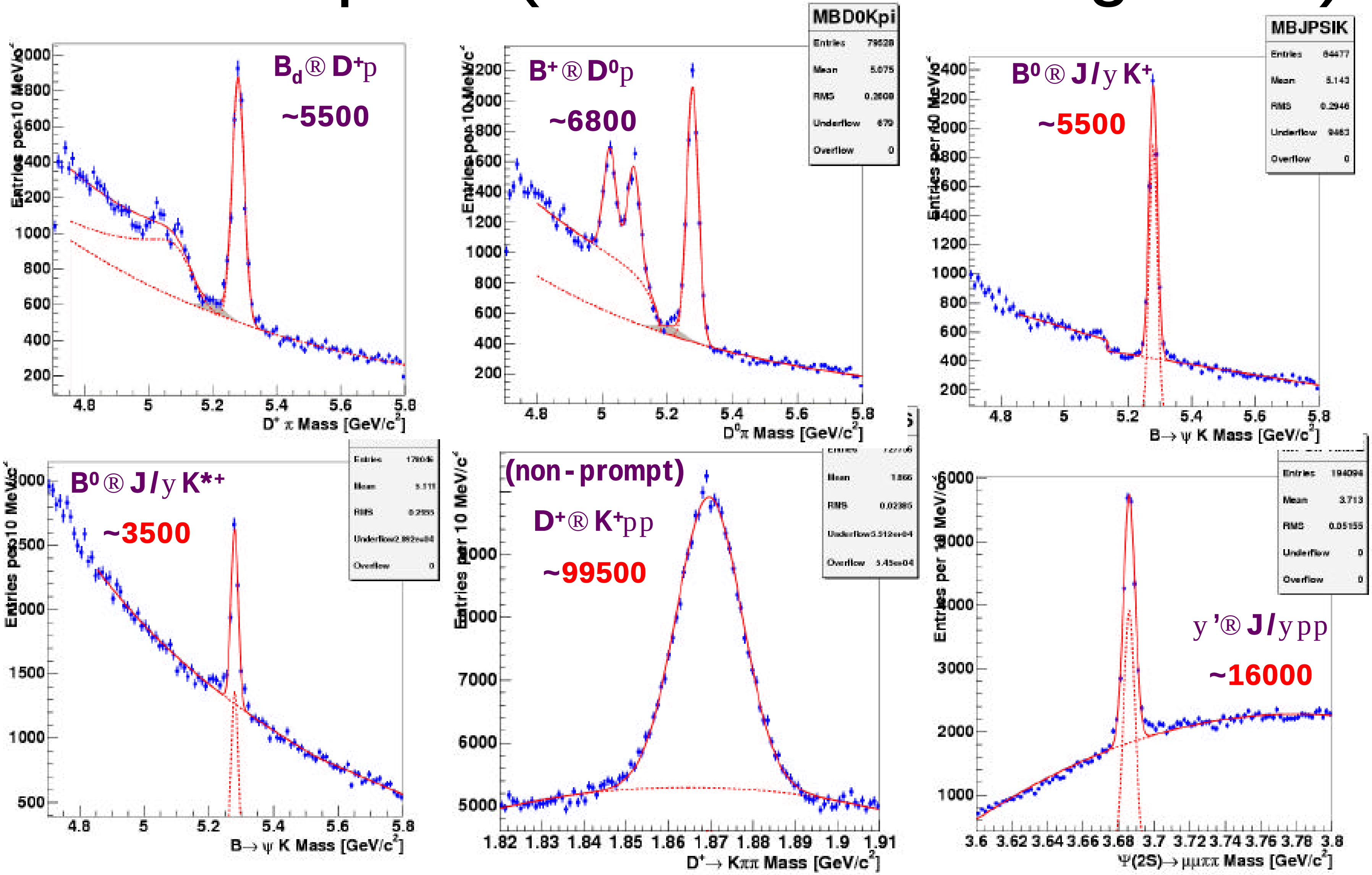
The samples (before relaxing cuts)



~15000 fully reco'd B, ~69000 Fully reco'd D+, ~6000 fully reco'd ψ' (re-running)

Montecarlo: mostly BGEN (basically all of the above+B_s), using Pythia if possible

The samples (before relaxing cuts)



~22000 fully reco'd B, ~100000 Fully reco'd D+, ~16000 fully reco'd ψ'

Montecarlo: mostly BGEN (basically all of the above+B_s), using Pythia if possible

This comes with a price though!

	$J/\psi K^+$ BGEN	$J/\psi K^+$ Pythia	$J/\psi K^+$ Data	$J/\psi K^{*+}$ MC	$J/\psi K^{*+}$ Data	$K^+\pi\pi$ MC	$K^+\pi\pi$ Data	$J/\psi \pi\pi$ MC	$J/\psi \pi\pi$ Data
N-1 L_{xy} Pull	1.18±0.02 ±0.4	1.24±0.016 ±0.12	1.35±0.017 ±0.4	1.18±0.02 ±0.3	1.56±0.02 ±0.2	1.14±0.009 ±0.02	1.22±0.004 ±0.03	1.16±0.02 ±0.1	1.21±0.01 ±0.2
N-1 d_0 Pull	0.97±0.02 ±0.3	1.13±0.014 ±0.07	1.19±0.014 ±0.4	0.99±1.3 ±0.2	1.31±0.02 ±0.2	1.08±0.008 ±0.02	1.02±0.003 ±0.03	1.04±0.02 ±0.1	1.11±0.008 ±0.3
MC X_{SV} pull	1.30±0.02 ±0.01			1.23±0.02 ±0.01		1.13±0.01 ±0.15		1.21±0.02 ±0.04	
MC Y_{SV} pull	1.25±0.02 ±0.2			1.28±0.02 ±0.09		1.14±0.01 ±0.2		1.27±0.02 ±0.15	
MC Z_{SV} pull	1.17±0.02 ±0.03			1.15±0.02 ±0.01		1.16±0.01 ±0.01		1.09±0.02 ±0.07	
MC Lxy Pull	1.15±0.02 ±0.04			1.18±0.02 ±0.04		1.17±0.01 ±0.15		1.20±0.02 ±0.01	

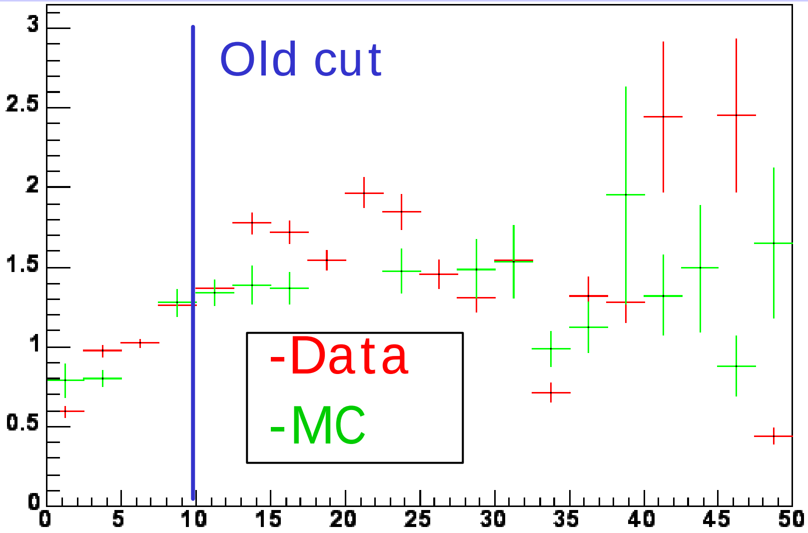
Large systematic uncertainties (up to 30%) and data/mc disagreement

Differences with last BPAK

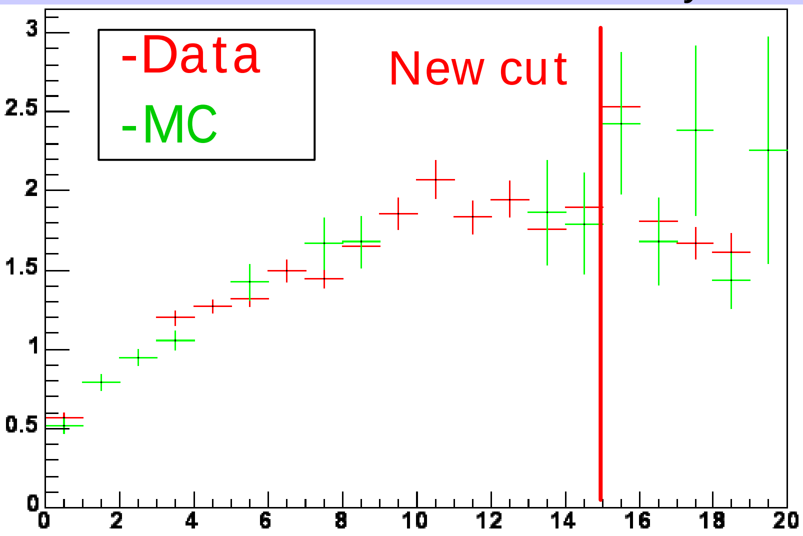
1) We gain in statistics
2) Secondary vertex pulls in general get larger
3) We pay a price: larger discrepancy between data and montecarlo

- The main source of 1) and 2) seems to be the χ^2 cut:

N-1 Lxy Pull vs χ^2_{3D}



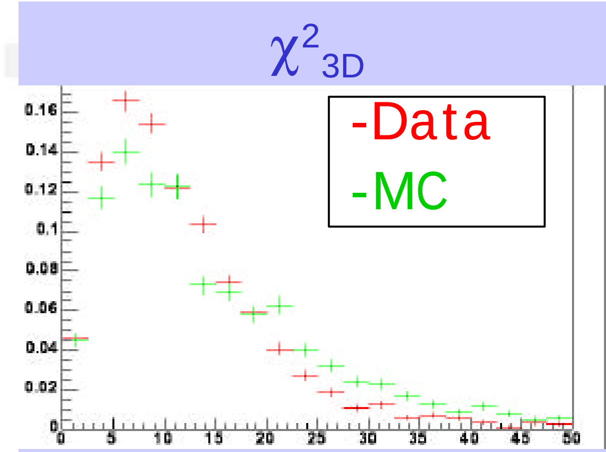
N-1 Lxy Pll vs χ^2_{xy}

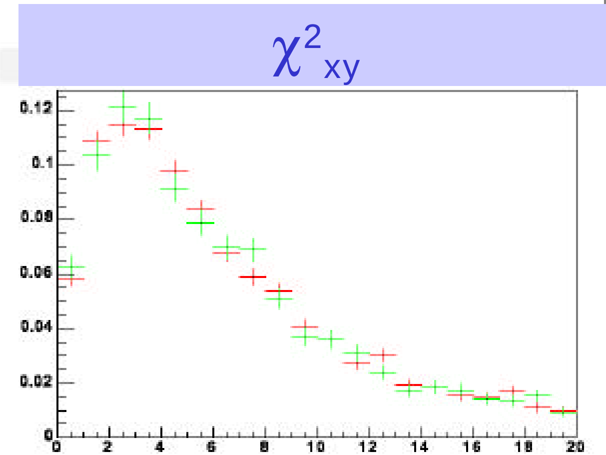


This does not quite explain 3), since agreement between data and MC seems pretty good!

Data-MC disgreement

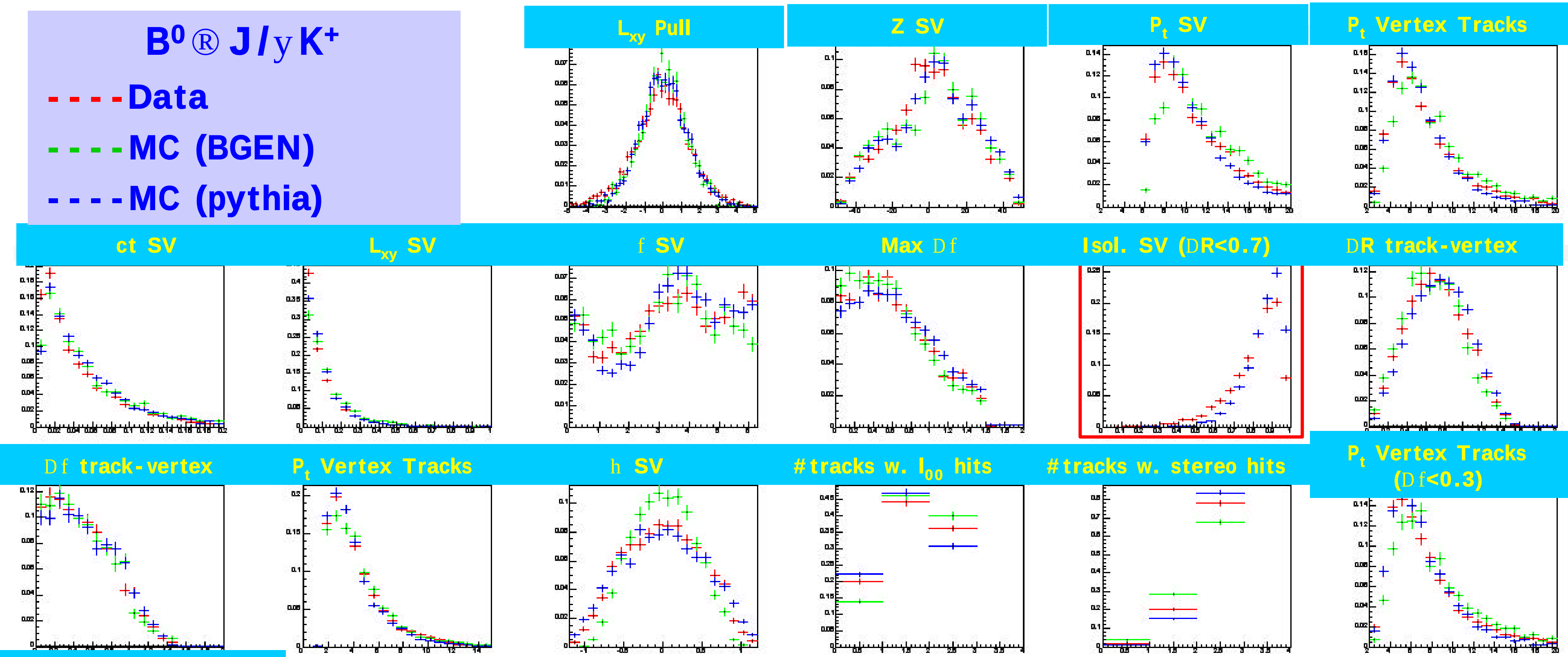
- Disagreement is as large as O(30%)
- Can't be neglected
- A difference in the distributions? (kinematics, geometry, chi2 etc.)
- χ^2_{3D} is not well reproduced, but we moved to χ^2_{xy}
- Other discrepancies?

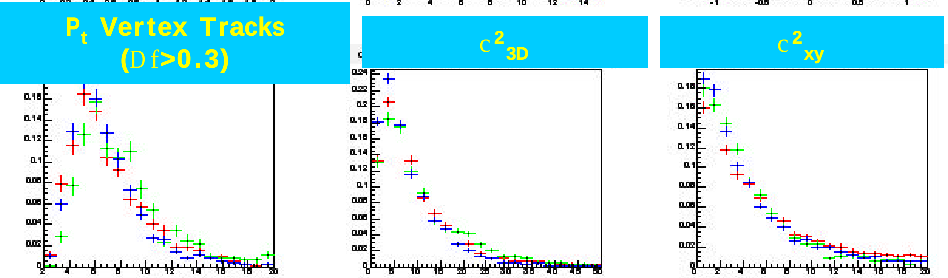




We compare systematically all the distributions and pull behaviors for the various samples, against MC

How different are distributions between data/MC?



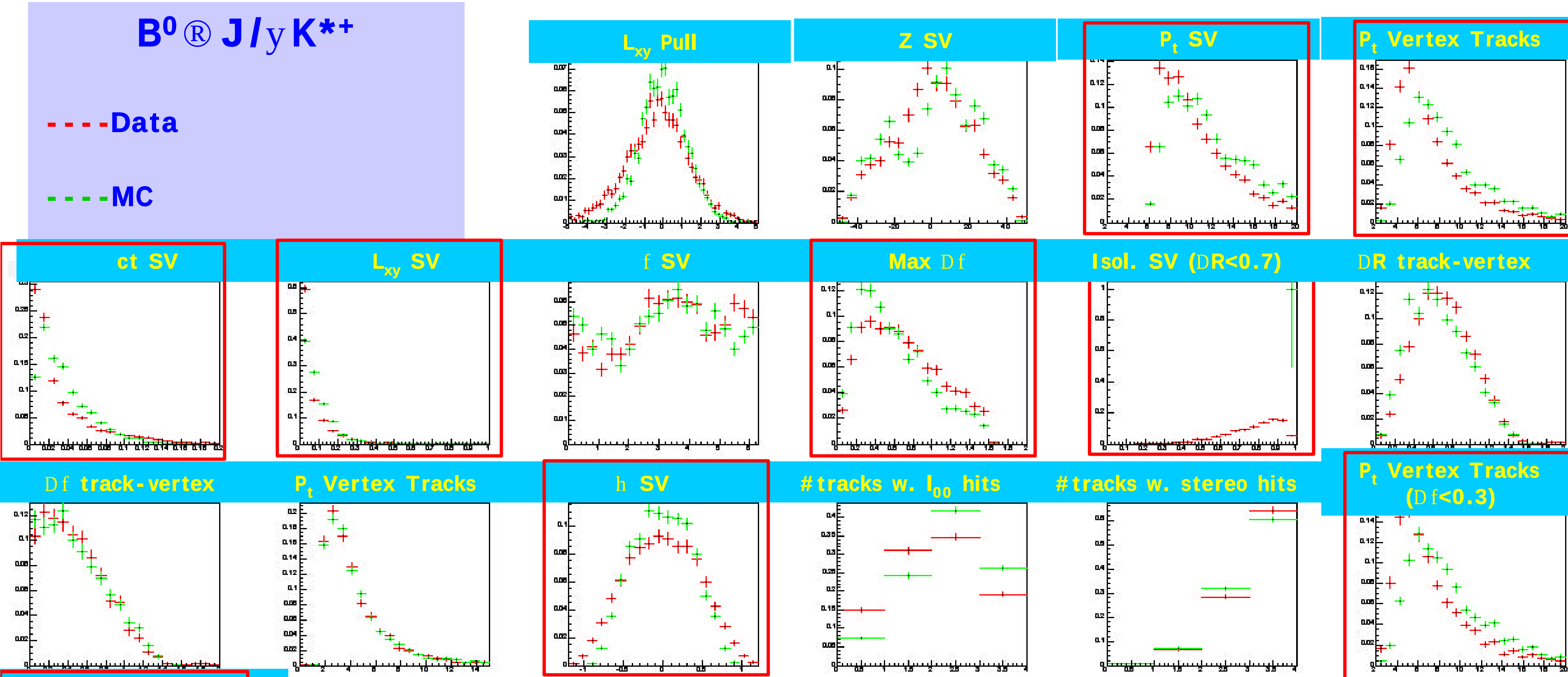


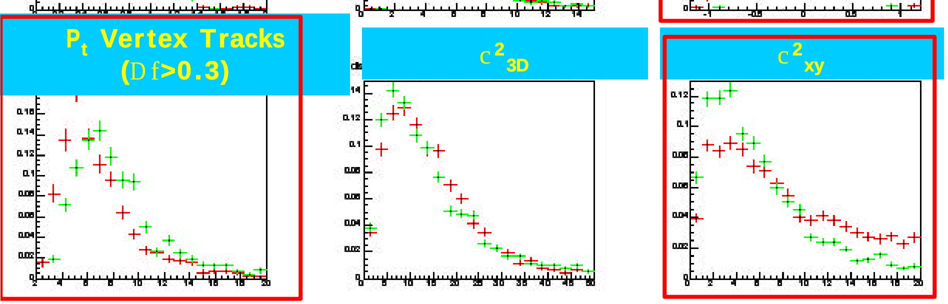
Red boxes show qualitatively different distributions:

- Isolation

Pythia shows pretty good agreement, BGEN has discrepancies in kinematics

How different are distributions between data/MC?

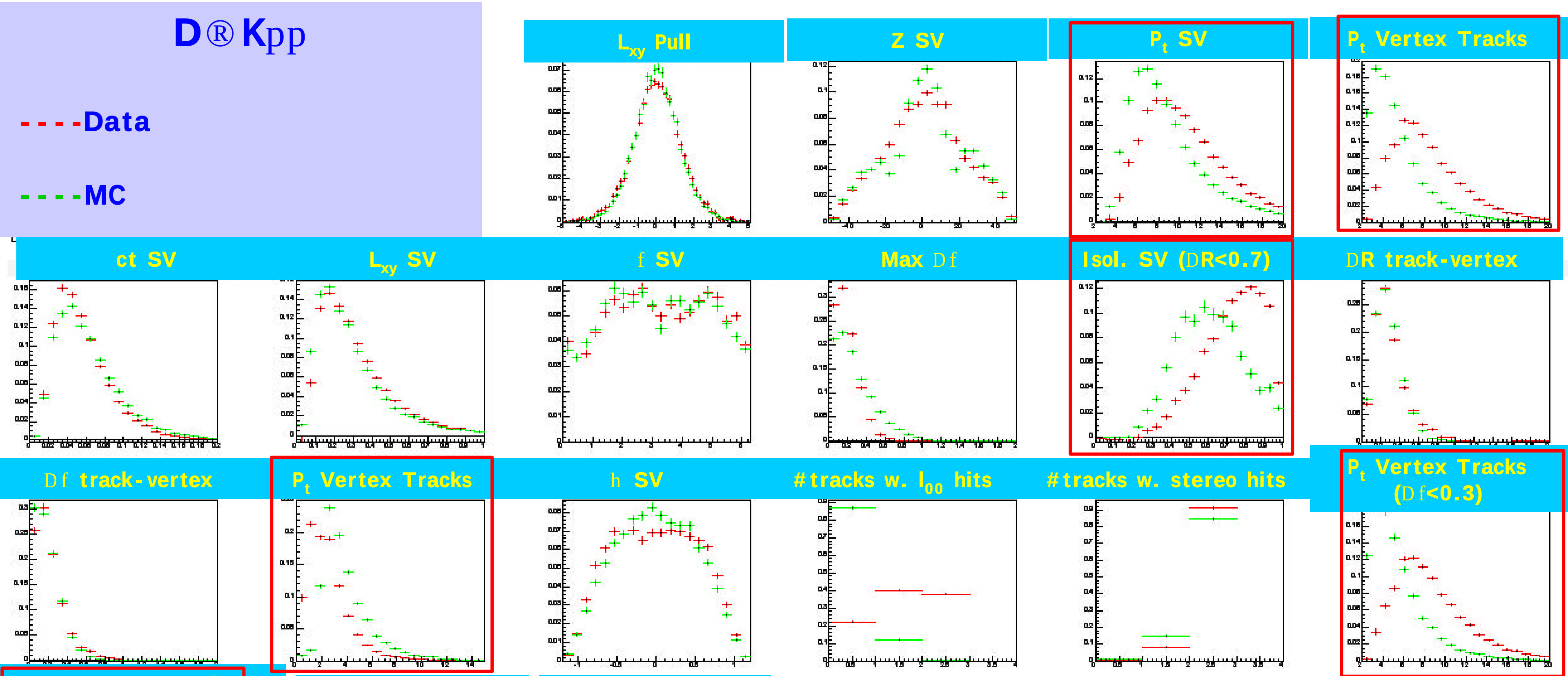


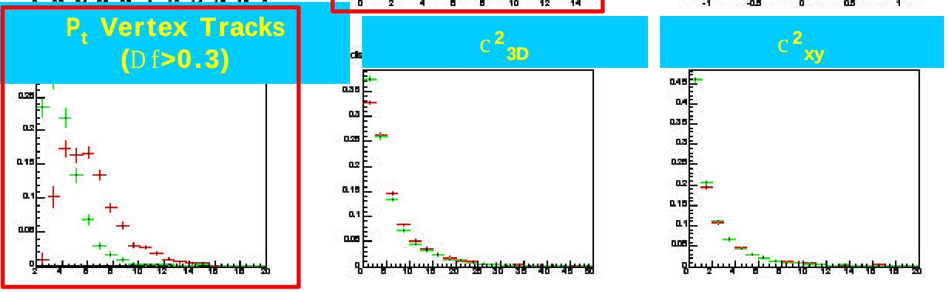


Red boxes show qualitatively different distributions:

- Kinematics
- χ^2_{xy}

How different are distributions between data/MC?

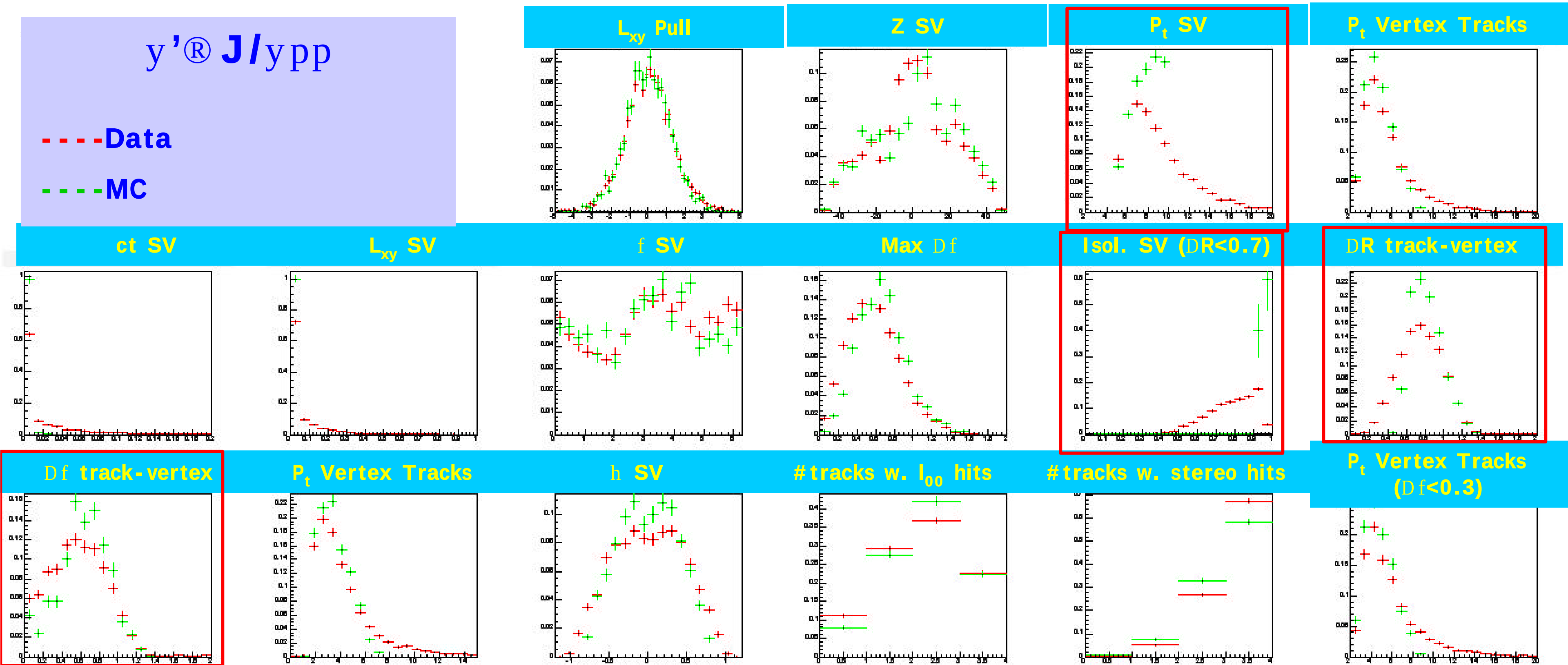


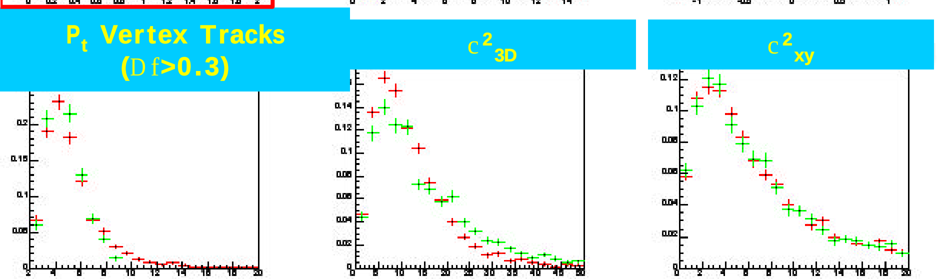


Red boxes show qualitatively different distributions:

- Kinematics
- Si hits assignment

How different are distributions between data/MC?



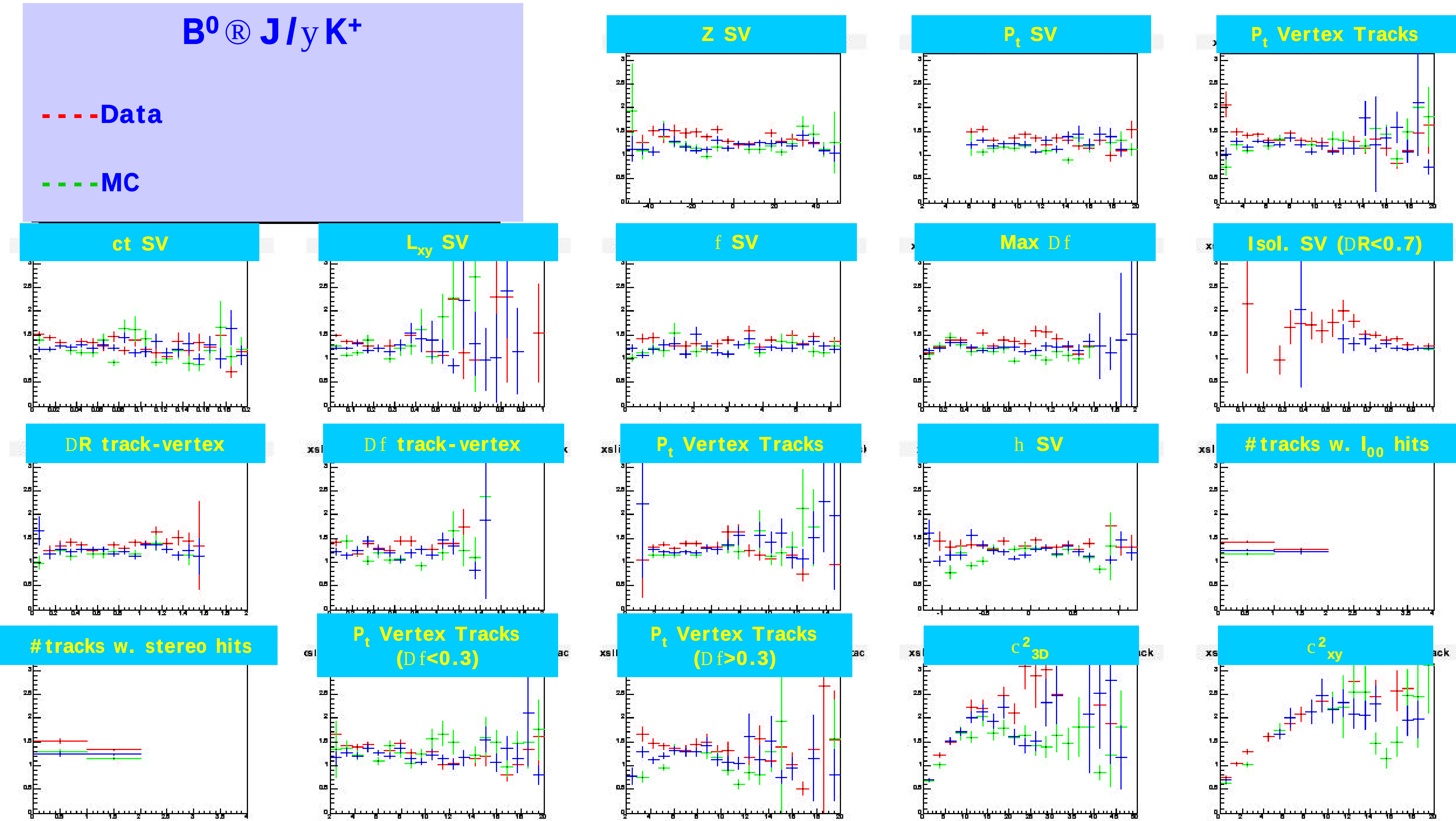


Red boxes show qualitatively different distributions:

- Kinematics

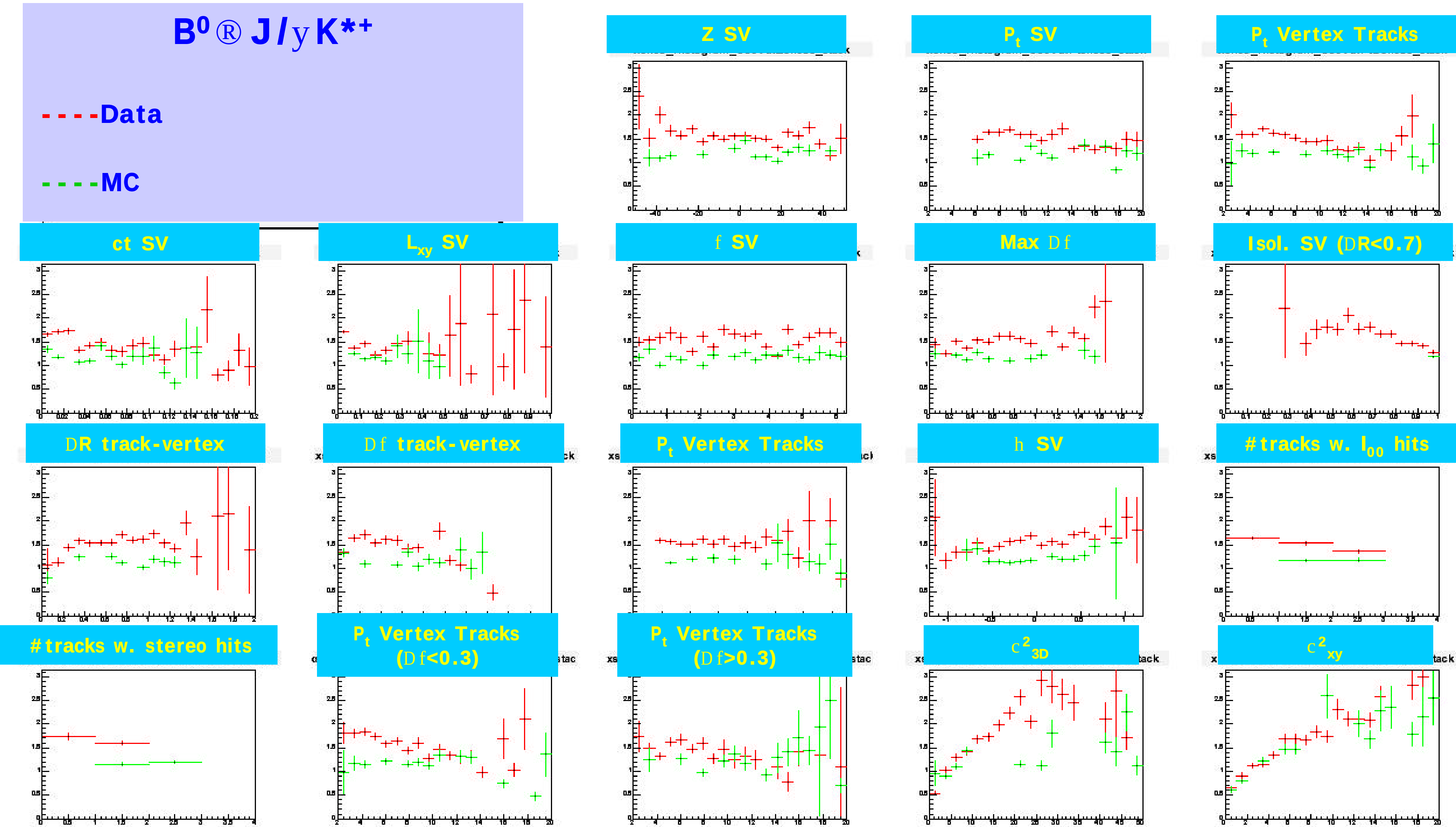
(MC generated with FakeEv)

How different are pulls between data/MC?



No statistical evidence of pull dependence, except for χ^2

How different are pulls between data/MC?



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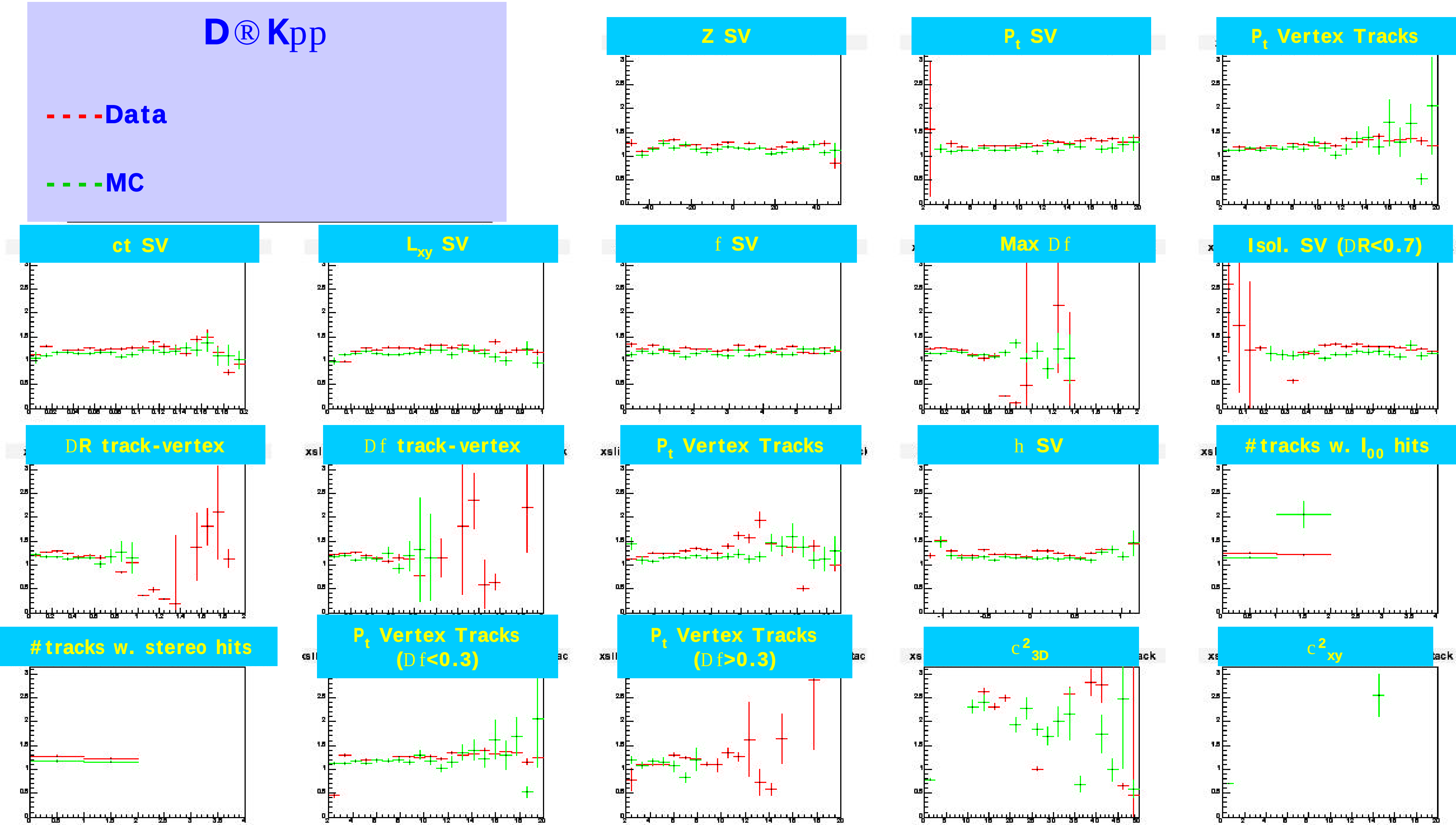

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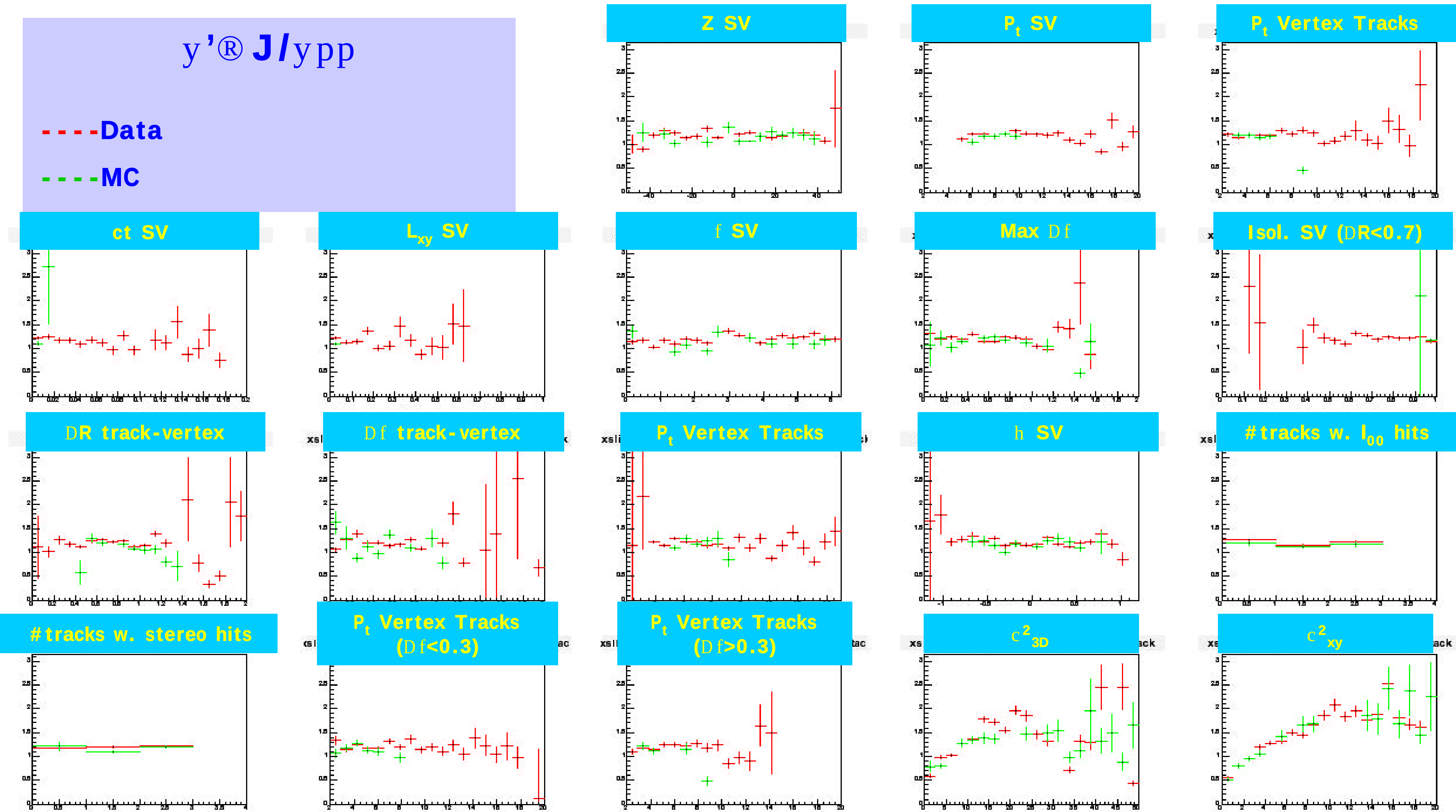


No statistical evidence of pull dependence, except for χ^2

Bottomline

With larger statistics, better cuts:

- No more dependence on ct/L_{xy}
- Kinematics MC and data differ significantly
- However Pulls don't seem to depend on those
- Pulls do depend on χ^2 but this is expected since χ^2 can be expressed as a linear function of the pulls themselves!
- Pulls generally larger but far from the '7500 numbers (~1.3)

Repeating the ‘7500 approach

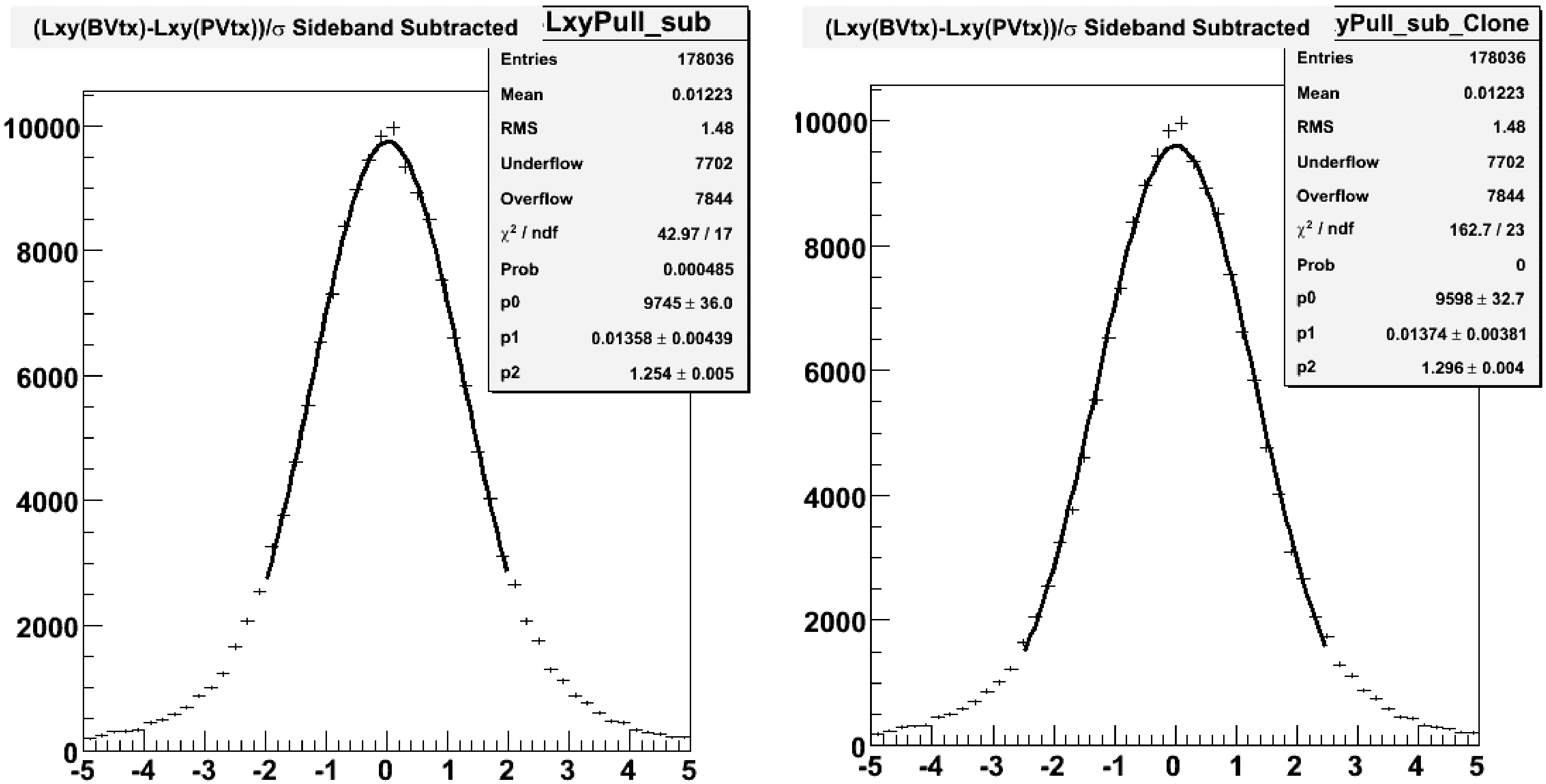
Strategy

- Same sample
- Same selections
  - $|d_0(D)|<100\mu m$
  - $|M_D - M_{PDG}|<8$ MeV
  - $5.4<M_B<5.6$
  - $\chi^2_{XY}<15$
- plus:
  - Right D-π charge (x0.5)
  - ΔR(all B/D daughters)<2
  - Lxy(D)>300 μm

    (~100% efficient because of trigger bias)
  - Pt(D)>5.5 GeV
- ~170K events (working on figuring out what's the source of the discrepancy in statistics!)
- Overall Lxy pull in good agreement with MIT fits: 1.316 ± 0.003 (width is rather sensitive on fit range & model though!)
- Dependencies?

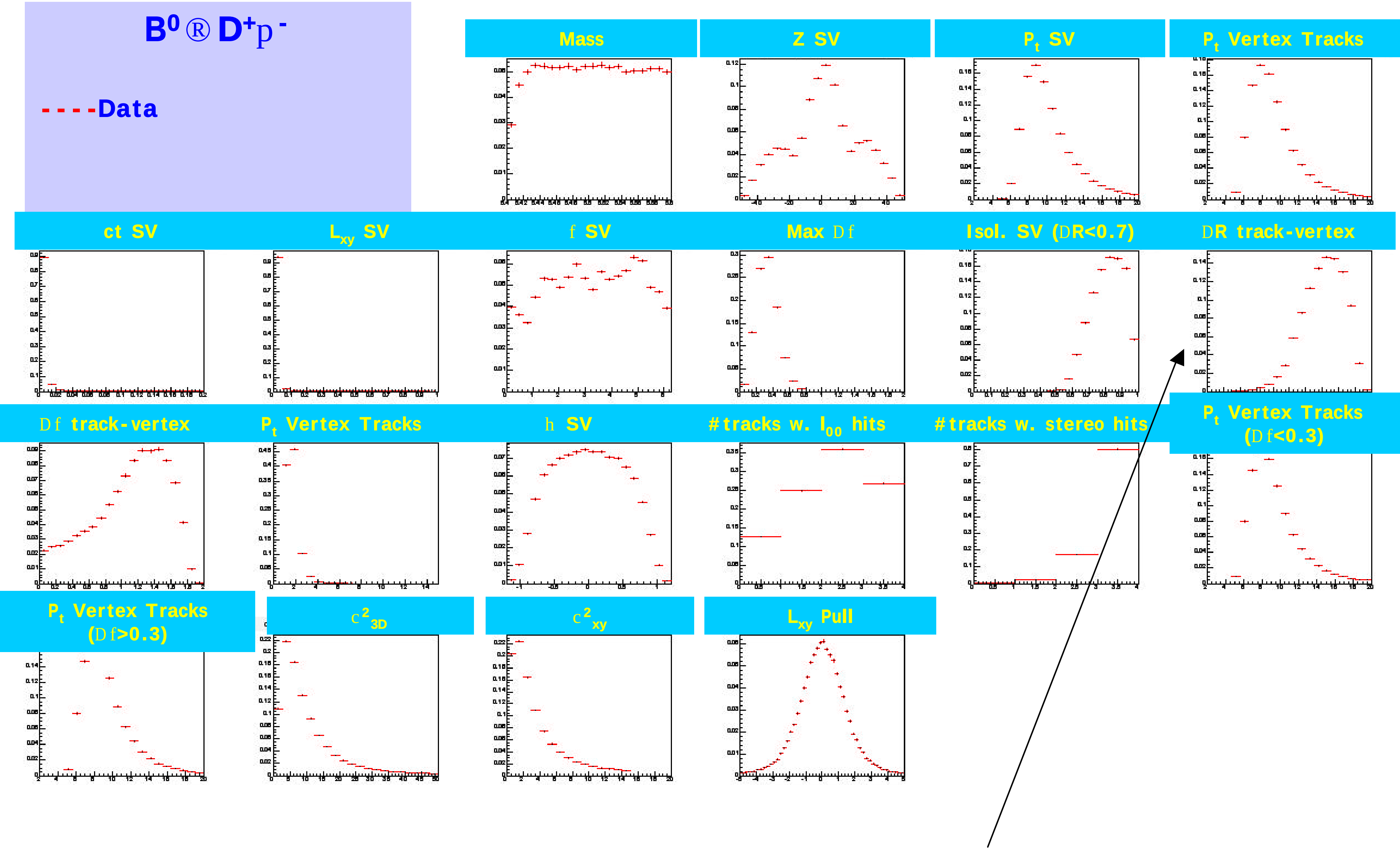
Caveat: Pull width depends a lot on fit details

Example: switch fit range from ±2 to ±2σ



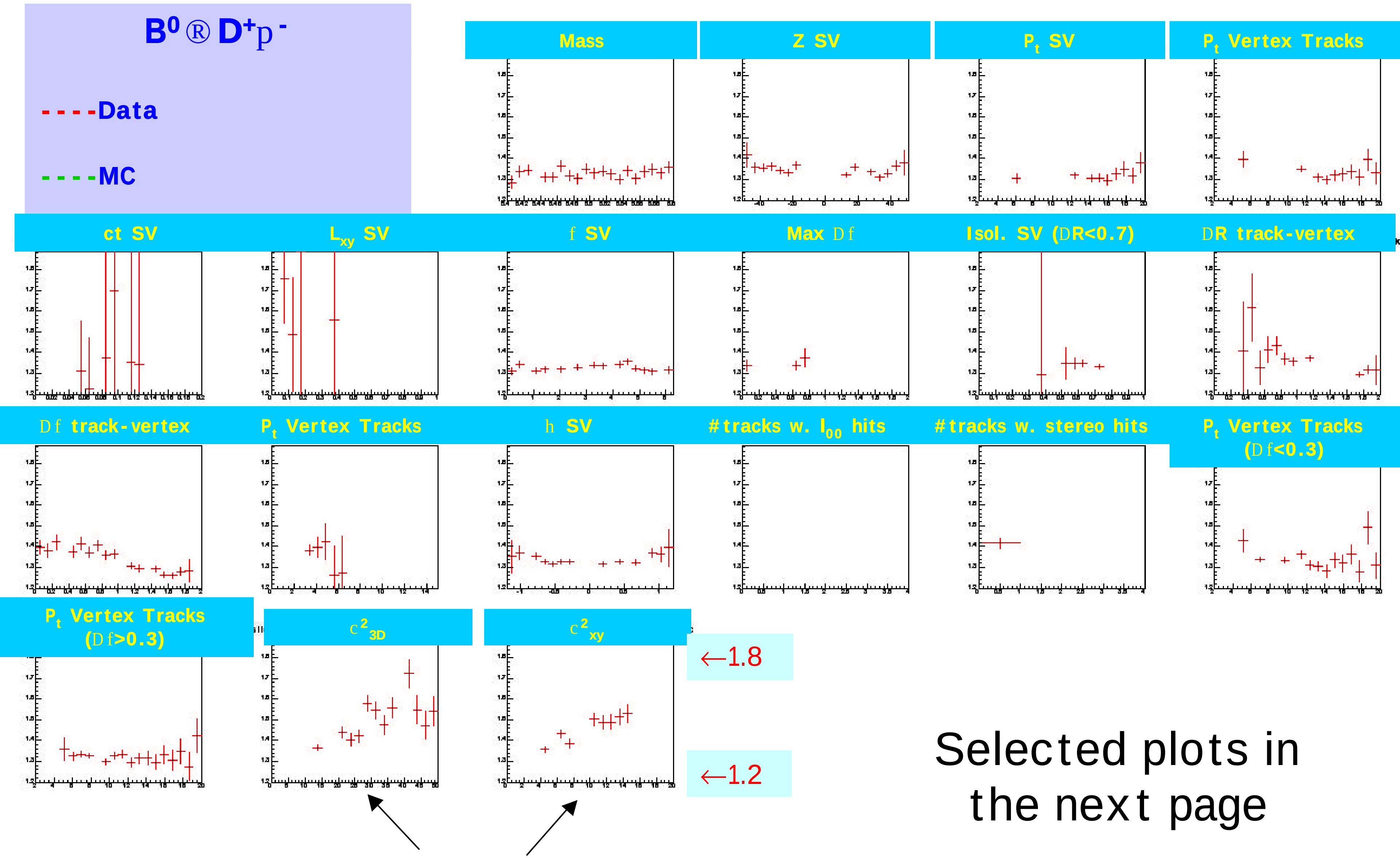
We must be very careful in defining what we want to really measure: even legitimate changes in the "model" can produce significant variations!

Distribution for “prompt” B→Dπ



ΔR(track-B) looks very different from real signal

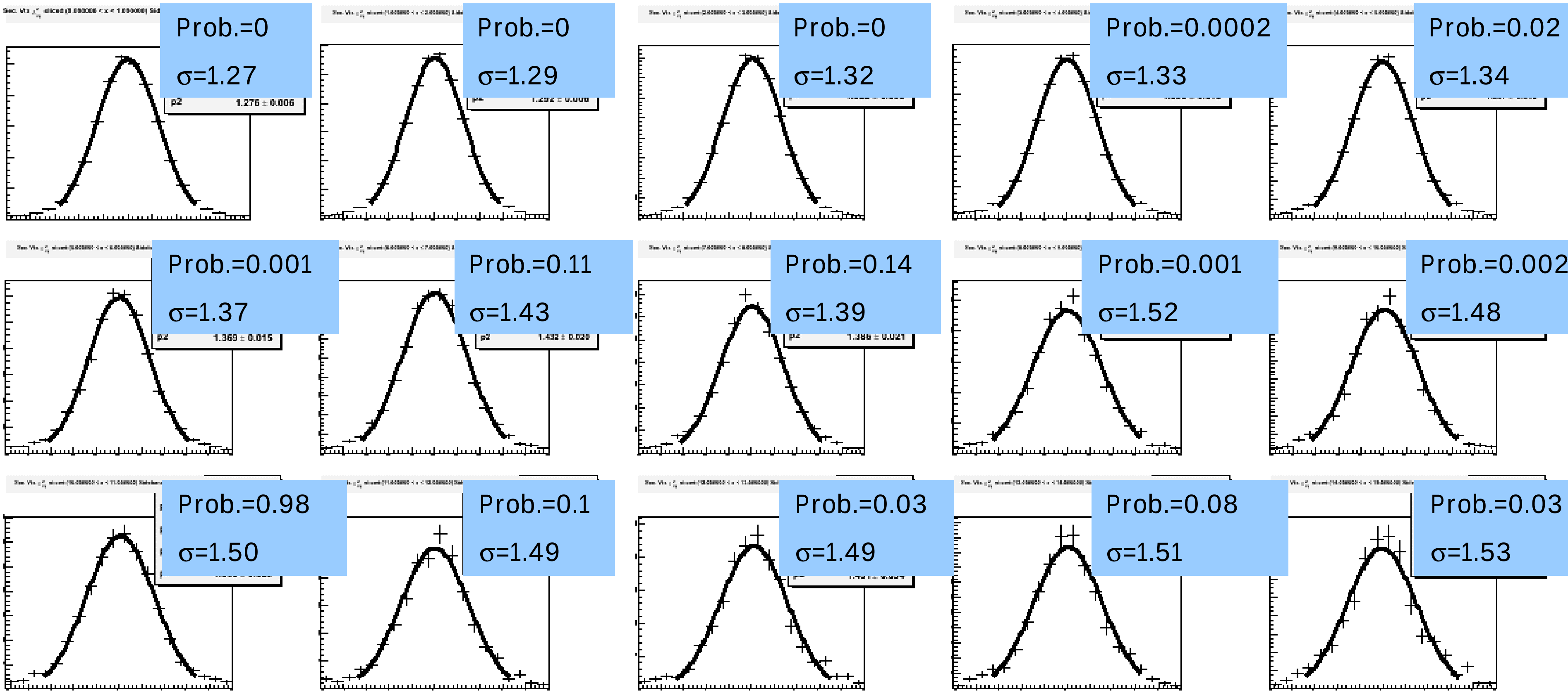
Pulls for "prompt" $B \to D\pi$



Selected plots in the next page

Significant dependence on χ^2

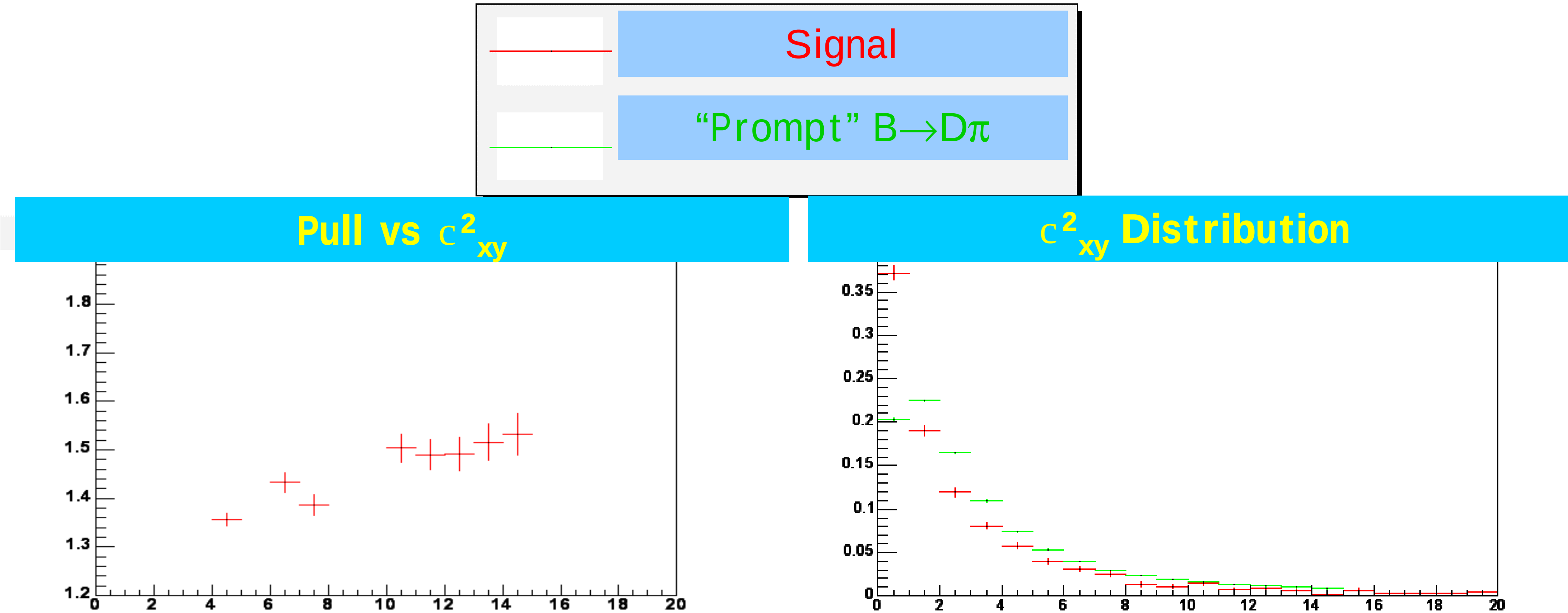
Example of Pull vs Chi fits



- Fit quality is good at low statistics
- Fit gets worse at low chi / larger statistics
- ...fit systematics dominates over statistical uncertainty...

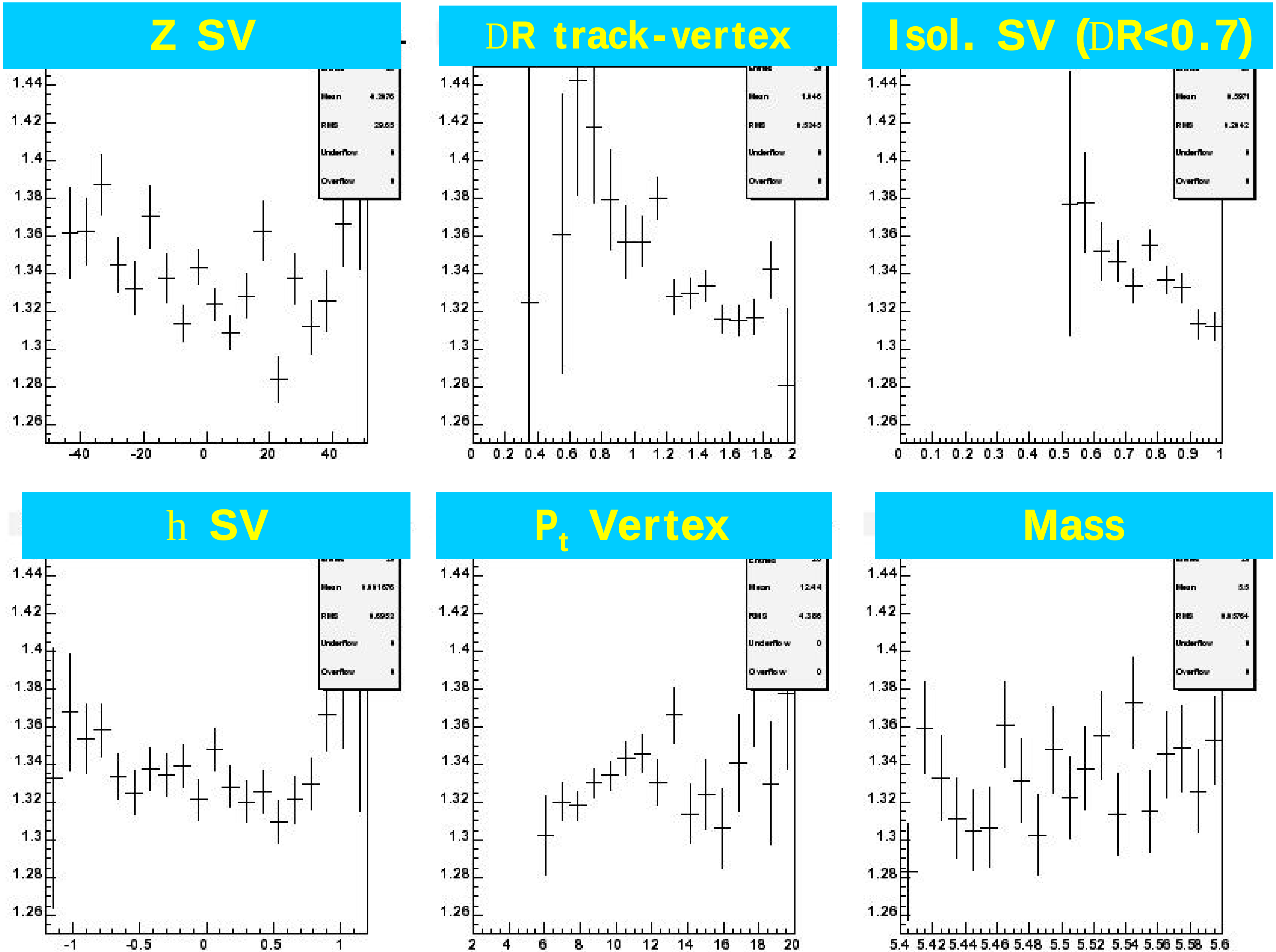
Pull depends on cuts and samples!

Width depends on chi2



- Pull definitely depends on χ^2
- χ^2 distribution is different between signal and "prompt" $B \to D\pi$

The ‘7500 plots



Bottomline

- We are able to roughly reproduce the '7500 quantity (L_{xy} of 'fake' B)
- Remember this is a quantity which is DIFFERENT from what we usually use in our study
- For this sample there are reasons to believe that χ^2 shouldn't be populated like for the signal:
  - Presence of D^+ and/or pions from secondaries will make it larger than in signal!
- L_{xy} pull is bound to grow indefinitely with χ^2 for "background"!
- Larger $\chi^2 \Rightarrow$ wider pull

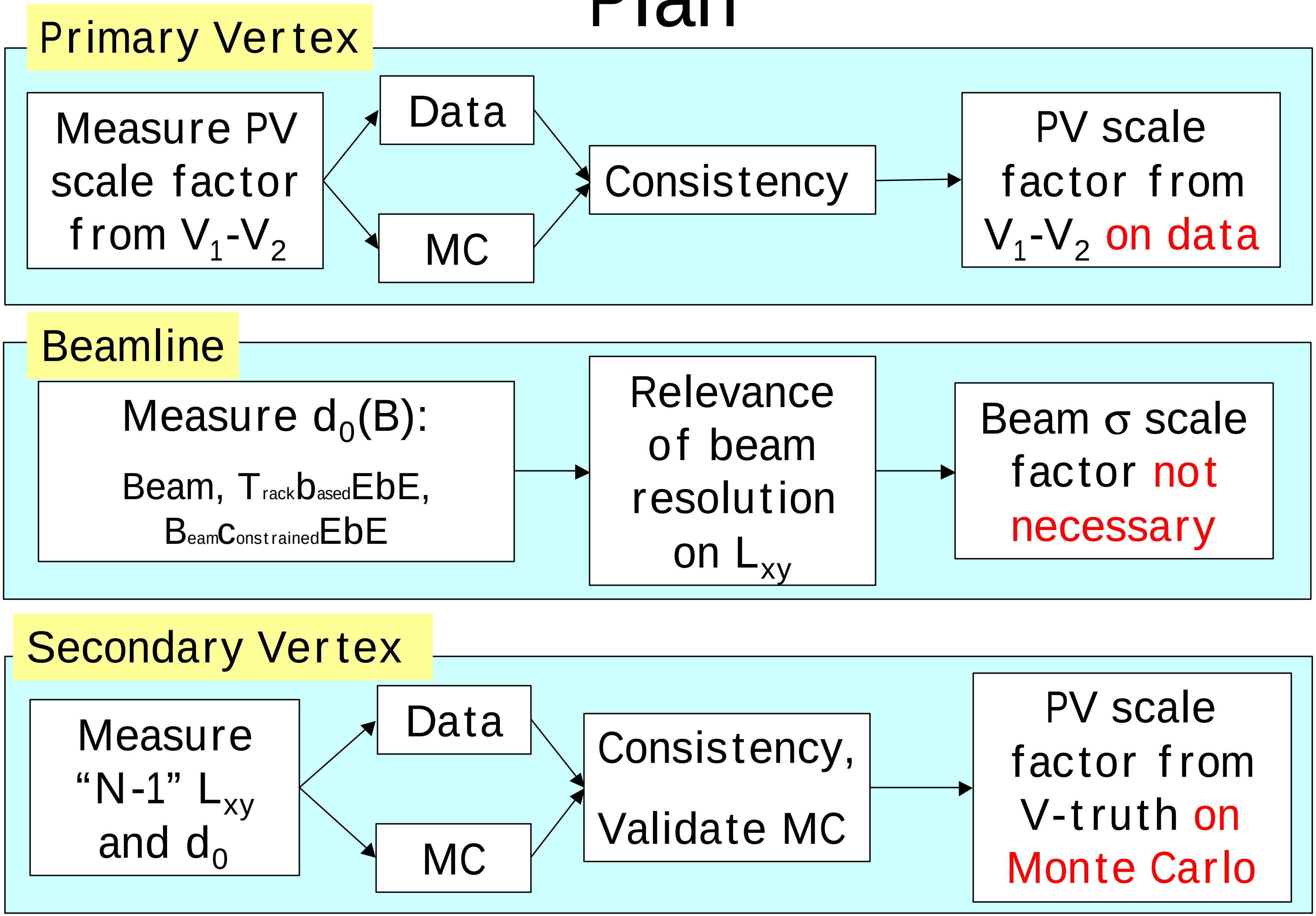
In any approach: a tight cut on χ^2 will reflect in a modification of the expected L_{xy} pull, no matter what the definition is!

Conclusions

- Changing cuts changes the scale factor
- Changing fit model changes the scale factor
- The scale factor is not really a “scale factor”: hidden dependencies
- A scale factor of 1.4 for the current analyses is “conservative” in terms of the limit we obtain
- For the future We know we can improve things!

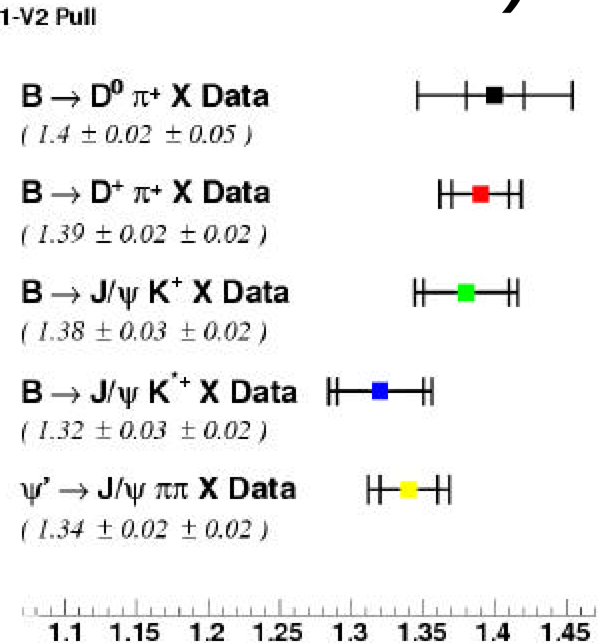
Backup

Plan


Primary Vertex
Measure PV scale factor from V_1-V_2
Data
MC
Consistency
PV scale factor from V_1-V_2 on data
Beamline
Measure d_0(B):
Beam, TrackbasedEbE, BeamconstrainedEbE
Relevance of beam resolution on L_{xy}
Beam σ scale factor not necessary
Secondary Vertex
Measure "N-1" L_{xy} and d_0
Data
MC
Consistency,
Validate MC
PV scale factor from V-truth on Monte Carlo

PV Scale Factor (no beam constr.)

- Can be probed directly on data using V_1-V_2
- Consistent picture in data: O(1.38)
- Monte Carlo after L00 re-weighting shows similar numbers (bottom right)
- Measured systematics from fit model and across samples [effect is O(5%)]



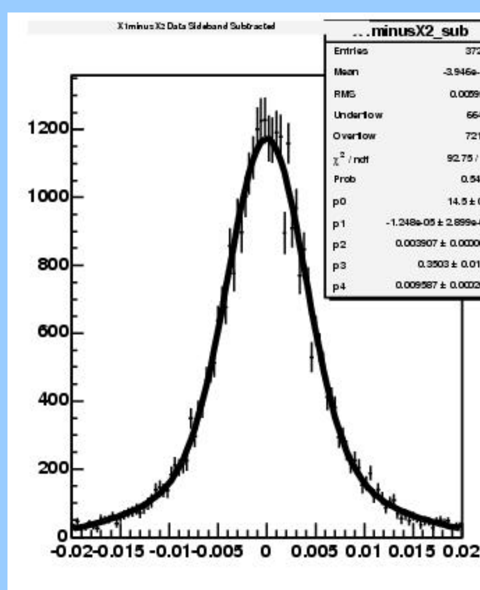
Pull fit:

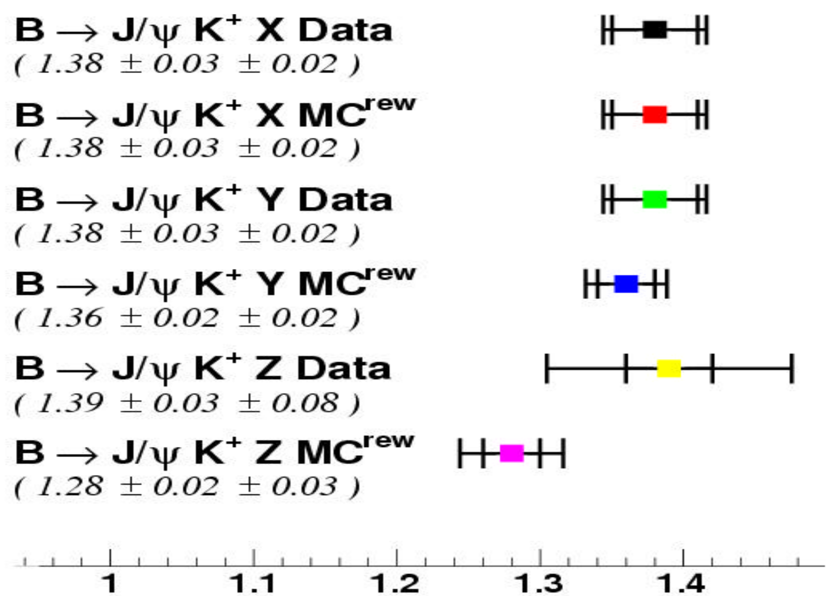
Reference:

- Gauss (±2σ)

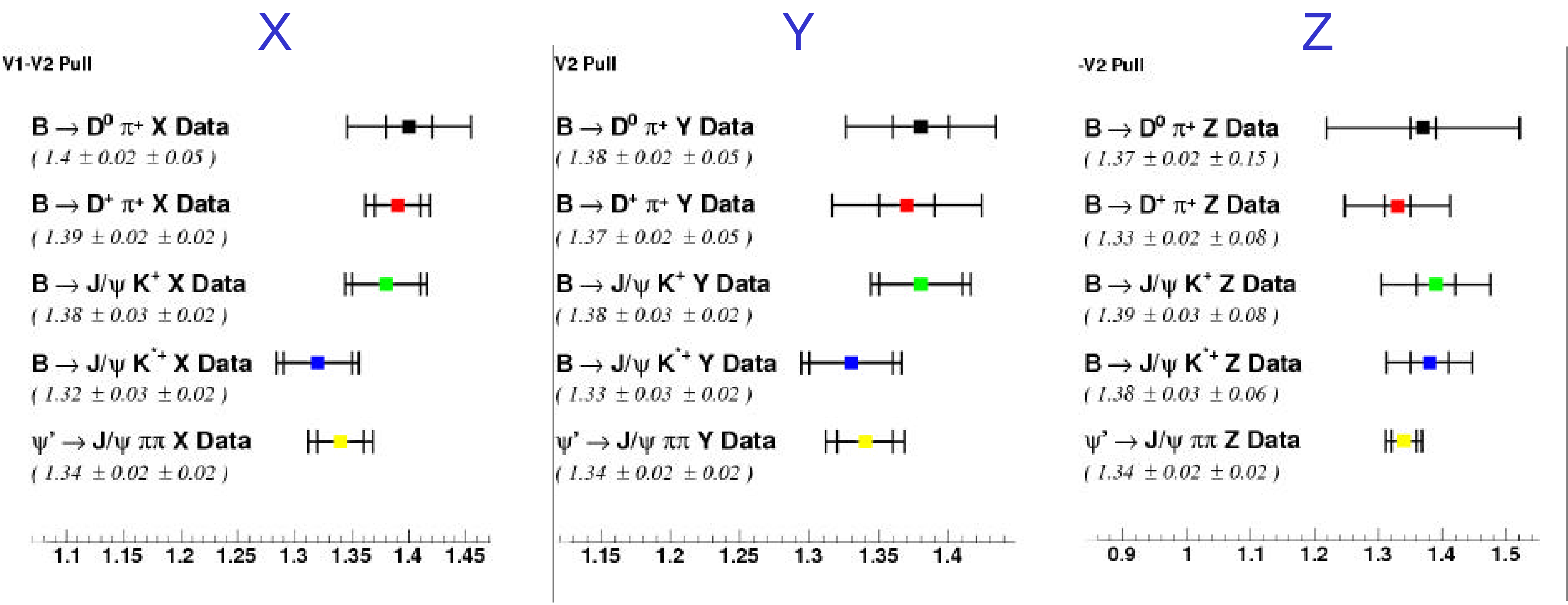
Model Syst.:

- Bigauss
- GaussExp





PV scale factor: other plots (X,Y,Z)

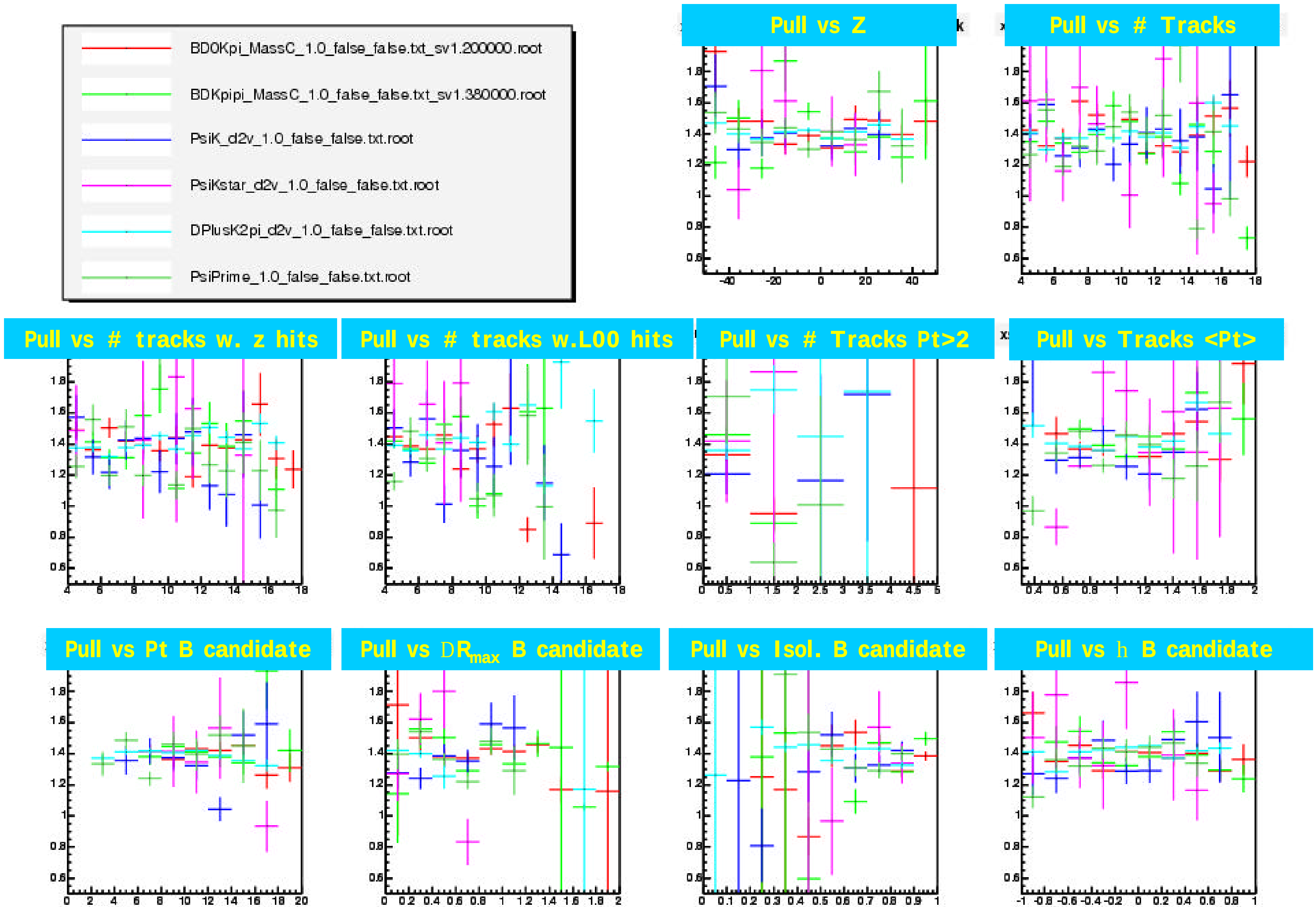


Pull uncertainty is dominated by:

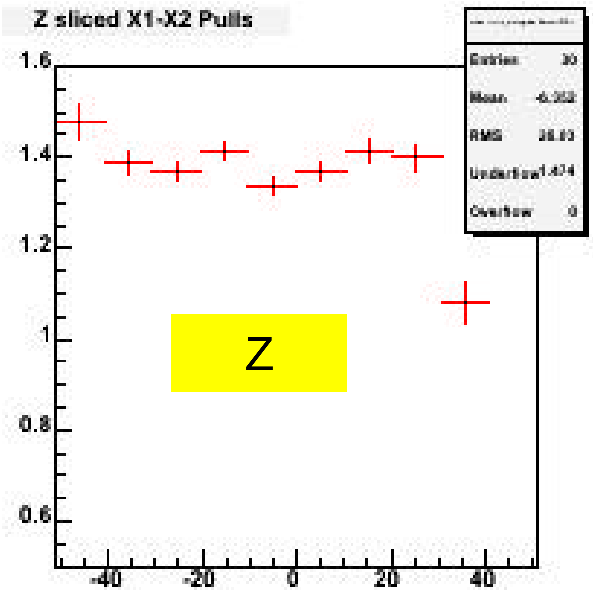
- Variability among samples
- Systematic uncertainty from fit model

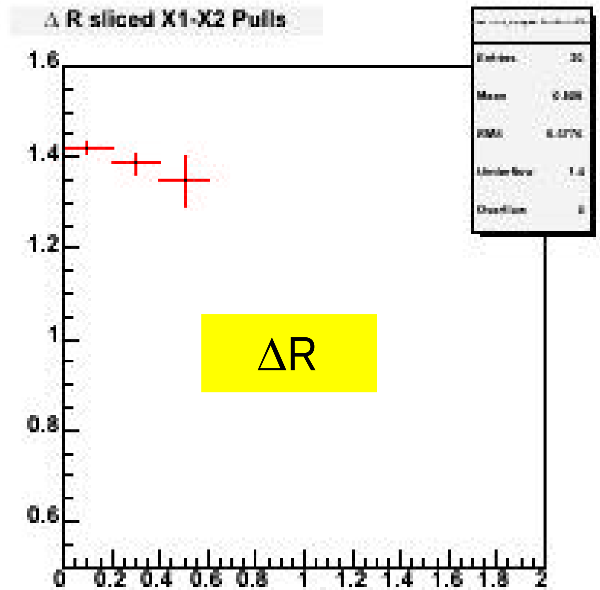
5% Uncertainty

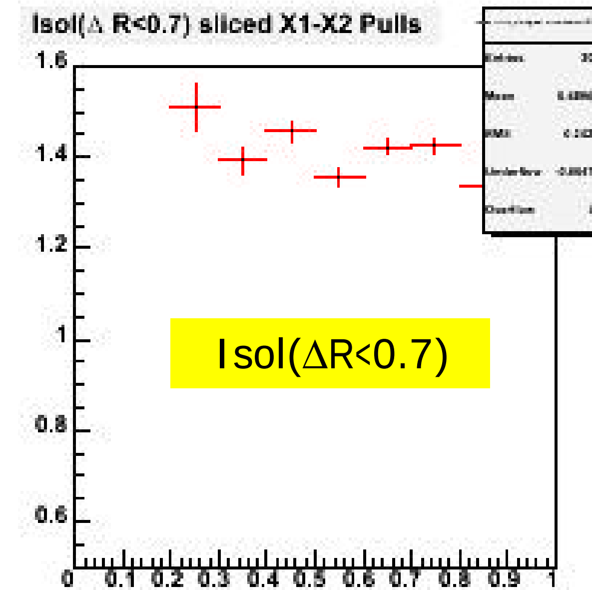
PV scale factor dependencies (X)

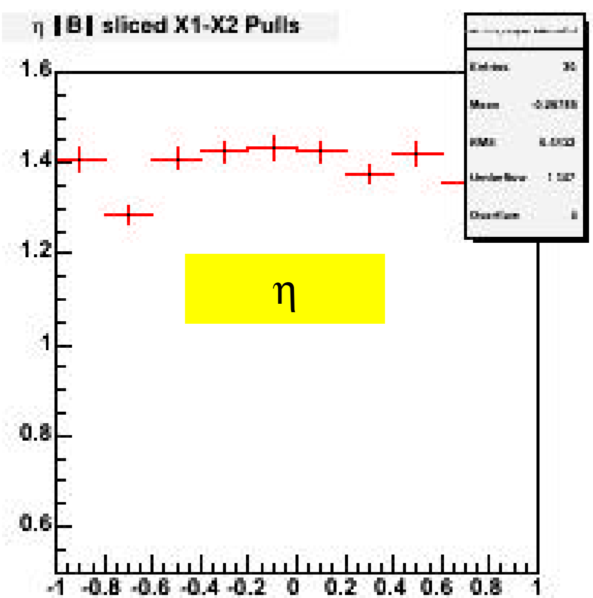


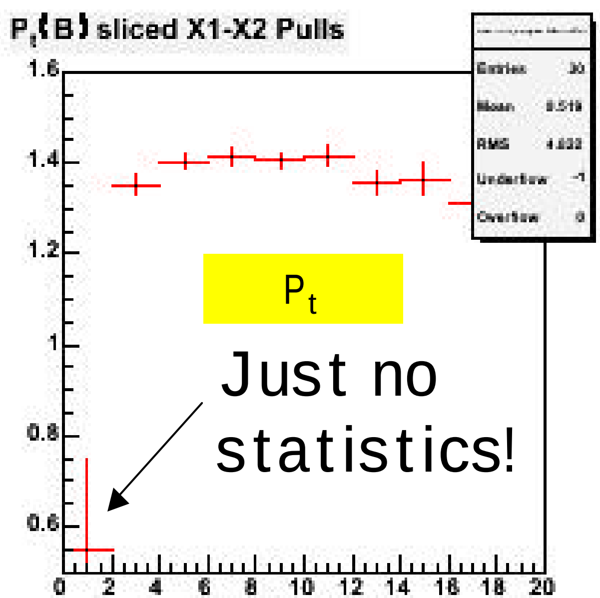
PV scale factor: details (à la CDF7500)











Non-statistical fluctuations dominated by fit model!

Conclusions on PV

- Scale factor measured on data
- Stable (within 5%):
  - Among samples
  - No evidence of dependencies
- We can move to the next step!

Beamline

Measure d_0(B):

Beam, TrackbasedEbE, BeamConstrainedEbE

→ Relevance of beam resolution on L_{xy}

→ Beam σ scale factor not necessary

$d_0(B)$: properties and limitations

Three possible ways of measuring PV:

1) Beamline
2) Track based Primary Vertex (TBPV)
3) TBPV constrained to beamline ("EbE")

What enters in $\sigma(d_0)$:

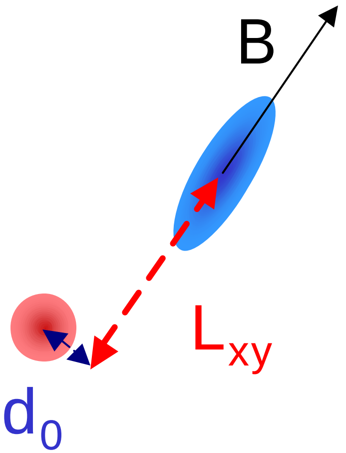
a) Beam (1,3)
b) Secondary vertex (1,2,3)
c) TBPV (2,3)

☹None of (1,2,3) probes only one piece!

☹Regime (relative contribution of a,b,c) differs between (1,2,3) but also between L_{xy} and d_0!

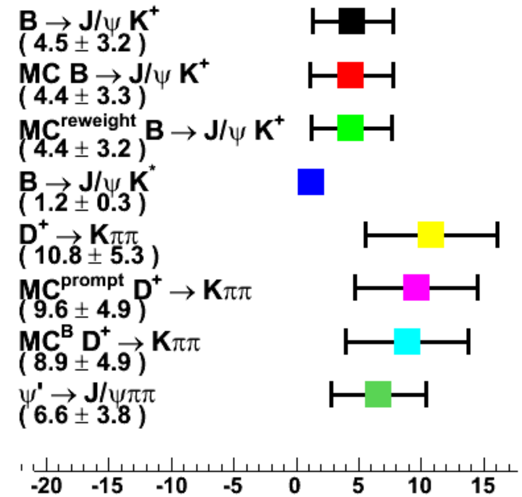
Let's see what happens in a real case...

Limit to the d_0 / L_{xy} analogy

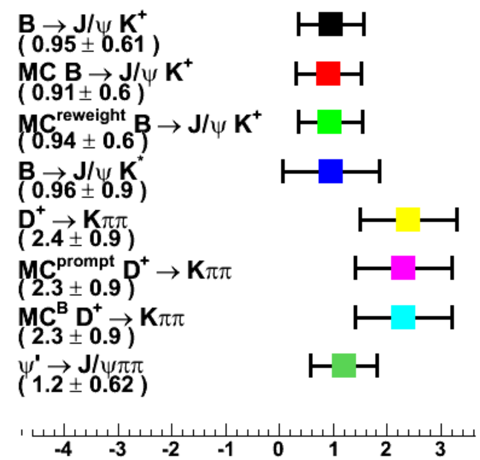


SV resolution ellipsoid is elongated and "seen from" different angles by d_0 and L_{xy} !

'D' Vertex error ellipsoid anisotropy (mean±RMS)



'D' Vertex error scale [in 100μm units] (mean±RMS)

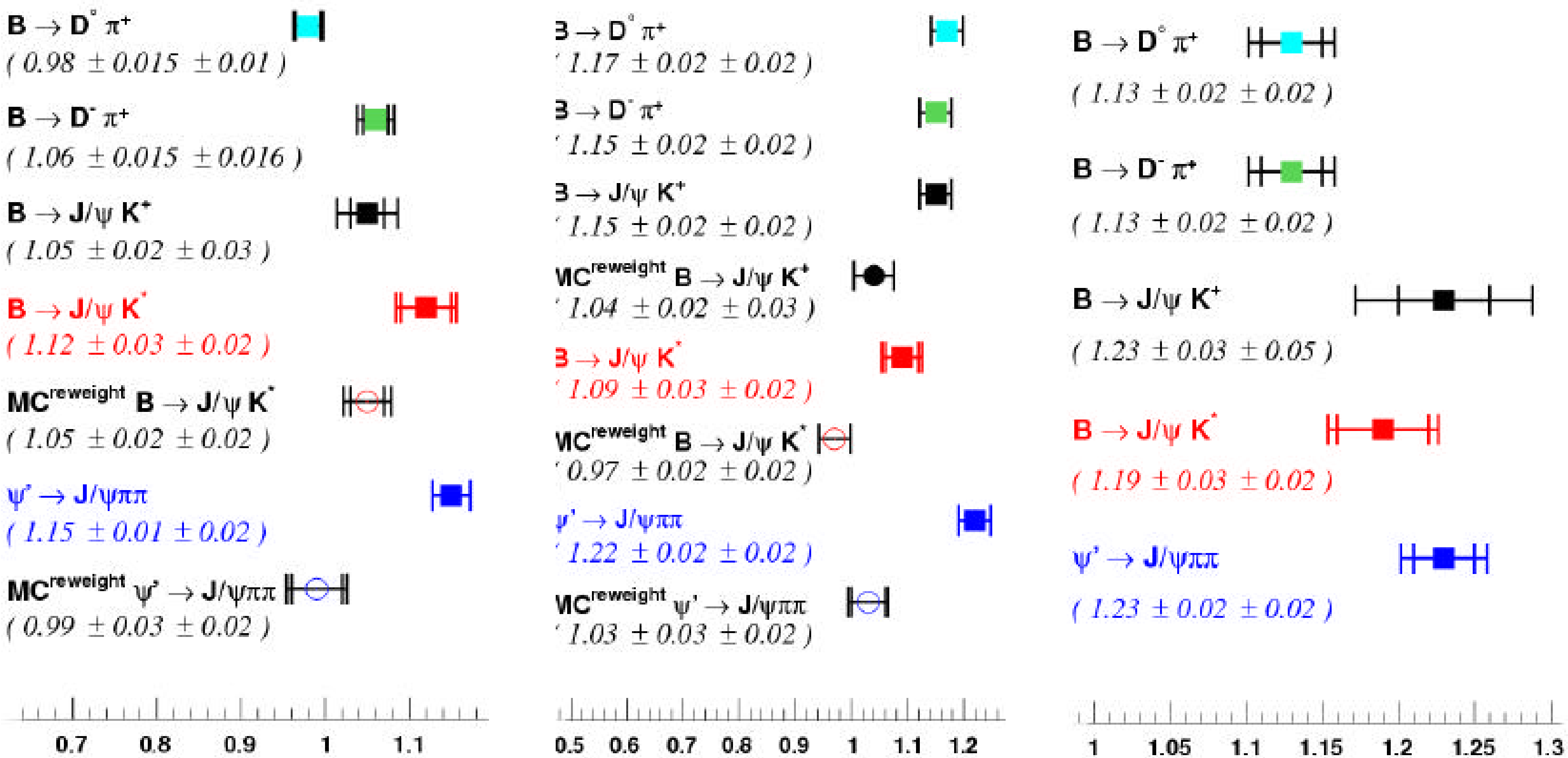


	Not Beam Constrained		Beam Constrained	
	σ_{d0}	σ_{Lxy}	σ_{d0}	σ_{Lxy}
PV	23	27	17	17
SV	12	36	12	36
Sum	27	45	21	43

d_0 and L_{xy} probe different regimes of σ_{PV}/σ_{SV}: d_0 dominated by PV, L_{xy} dominated by SV

Back to d_0: Comparison among samples and with MC

Track based EbE | Beamline | EbE (with beam constr.)



SV | Beamline and SV | Beamline and SV

Source of deviations from 1

Evidences of underestimate of beamline and SV errors!

Why blow-up on the beamline does not concern L_{xy}

Why 30%?

- Back-of-the-envelope calculations:
  - Typical 'long run'
  - Initial and final luminosities
  - On-line (SVT) beam width measurement confirms estimate
  - Tested on single run

Why it is of marginal relevance:

- Using 'average beam width' attenuates the effect: 30%→20%:

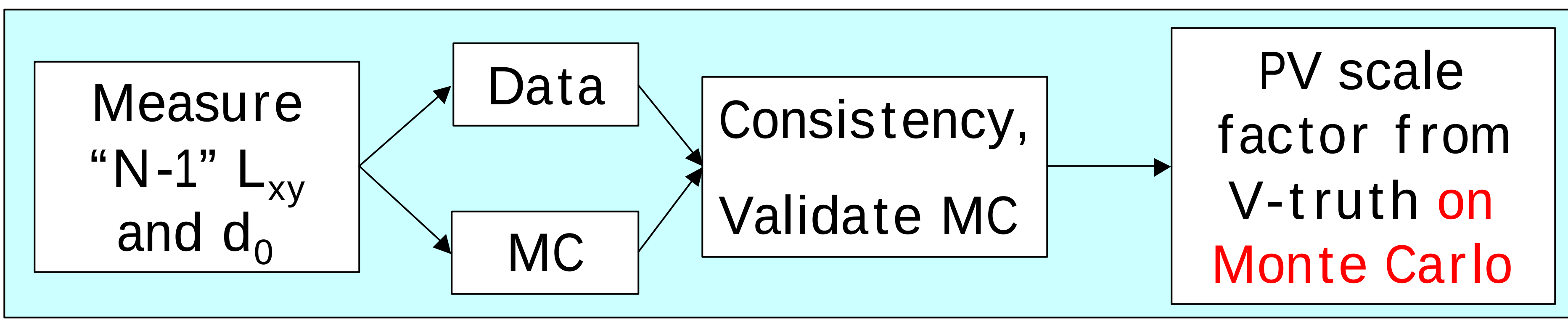
	σ [μm]	Pull [%]
L_{xy}	+0.5	+2%
d_0	+2	+6%

Other sources not investigated, however: not much of a concern for L_{xy}, relevant for d_0

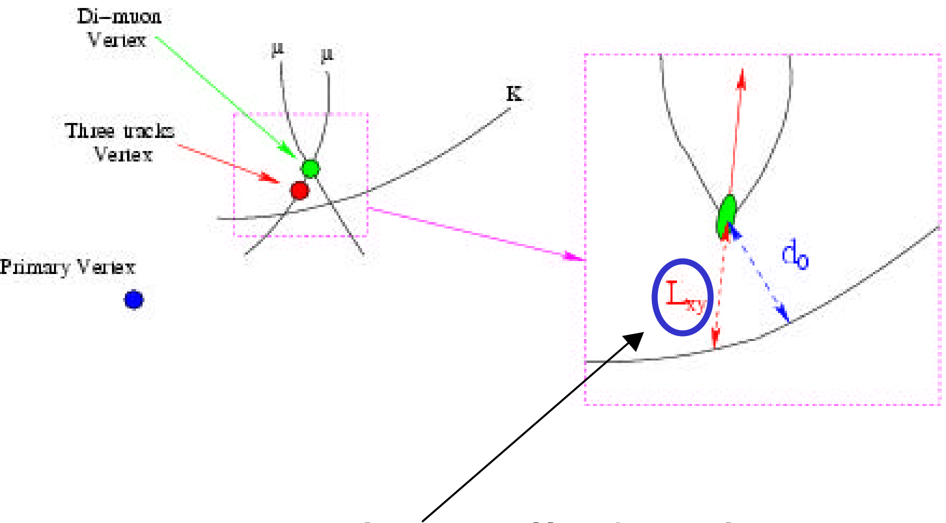
Bottom line

- d_0 pulls show effect of non unitarity of:
  - Beamline pulls
  - Secondary vertex pulls
- Restoring beamline pulls' unitarity is of marginal (2%) relevance for Lxy
- Let's move on to the secondary vertex!

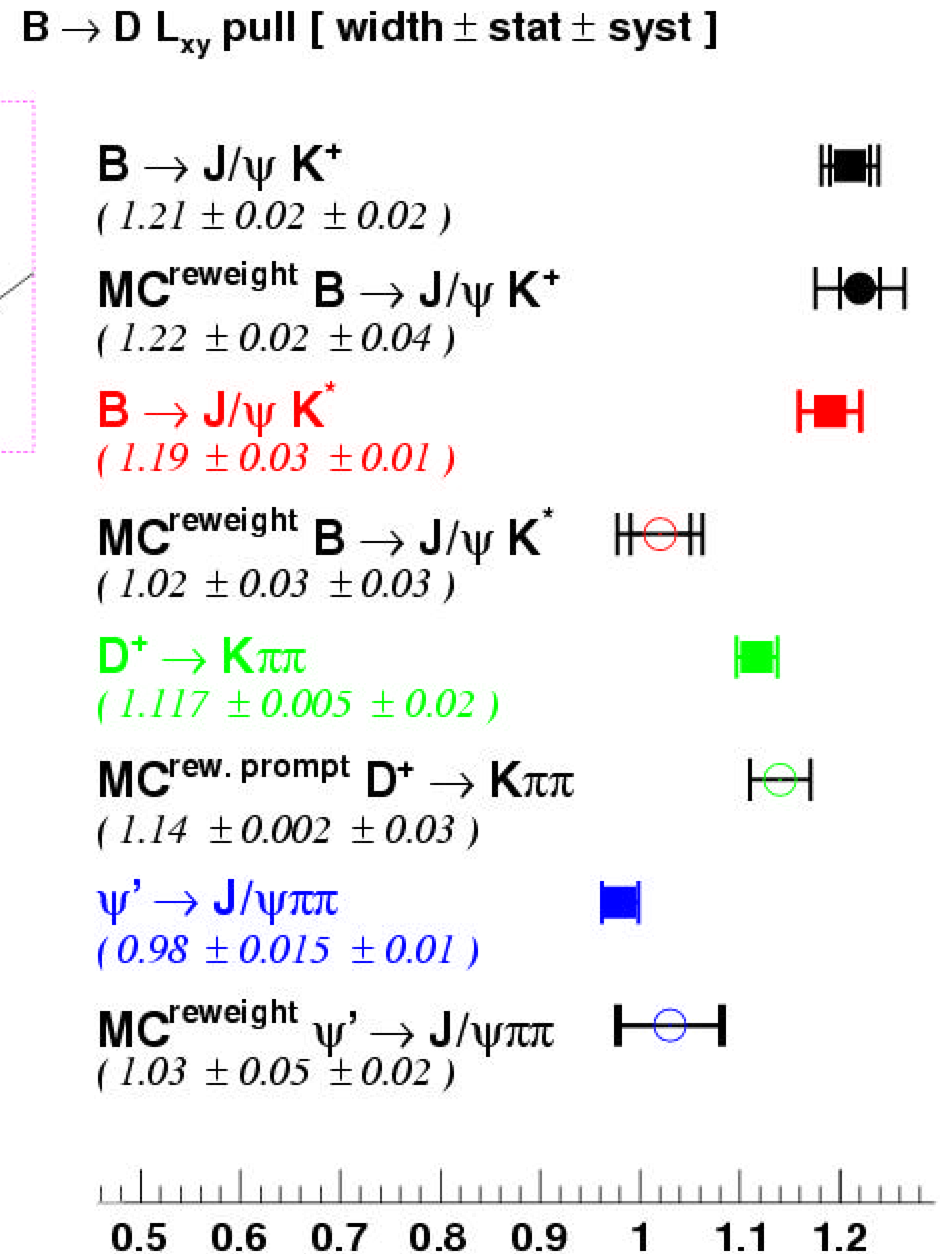
Secondary Vertex



"N-1" L_{xy}: data and MC



- Computed L_{xy} pulls for the various samples
- Compared to MC evaluation
- Pretty good agreement!
- MC seems to account for (possible) inter-sample variations and absolute scale of pulls!



Dependencies

Look for evidence of dependencies on geometry, kinematics etc:

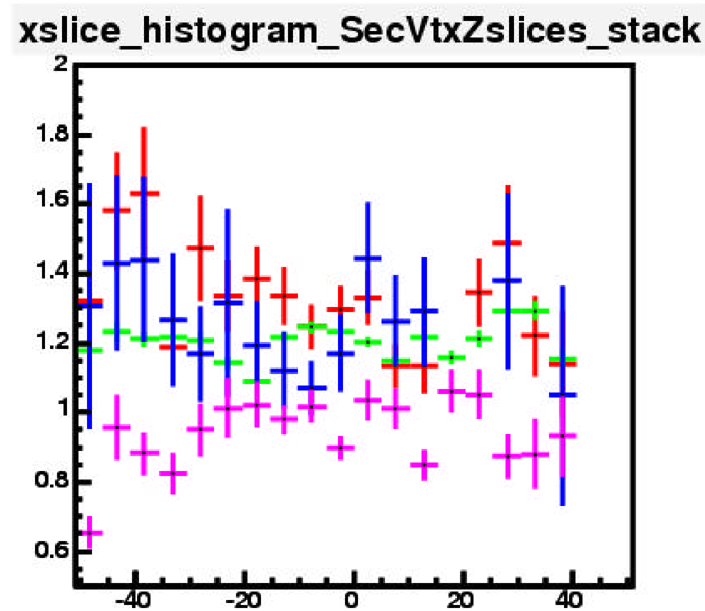
- Pick a suitable set of variables:

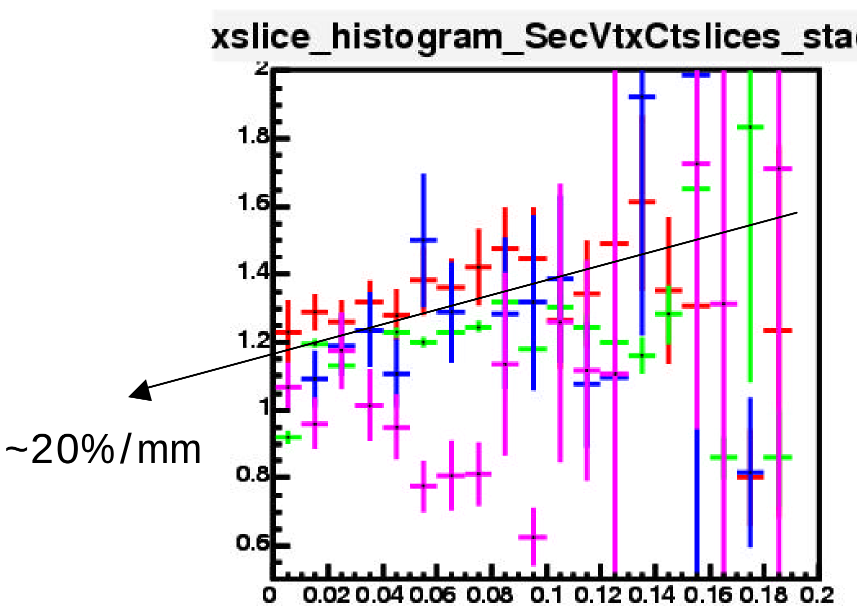
Z of SV	$\Delta\phi$ single track-rest of vertex
Pt of SV	Pt of single track
Combined Pt of tracks in SV	η of SV
Ct of SV	# tracks with L_{00} hits in SV
L_{xy} of SV	# tracks with stereo hits in SV
ϕ of SV	Combined Pt of tracks in SV ($\Delta\phi$<0.3)
Isolation of candidate B (ΔR<0.7)	Combined Pt of tracks in SV ($\Delta\phi$>0.3)
ΔR single track-rest of vertex	

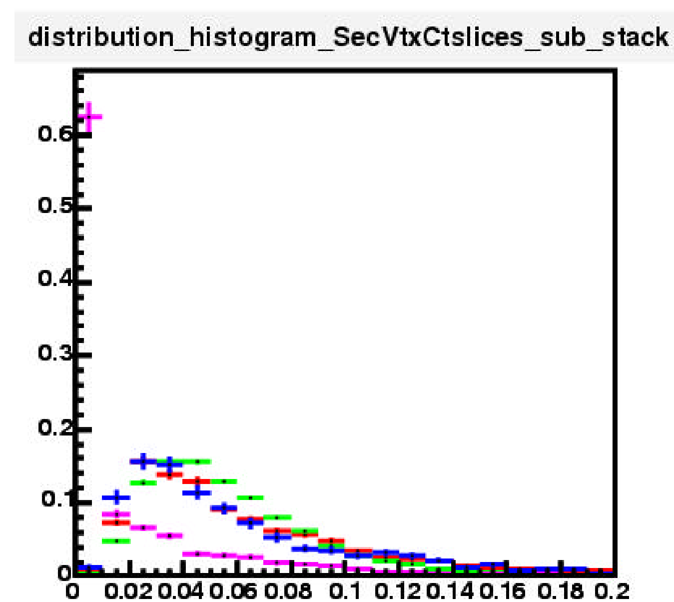
- Compare how various samples probe them
- Check pull vs variables

Selected Plots

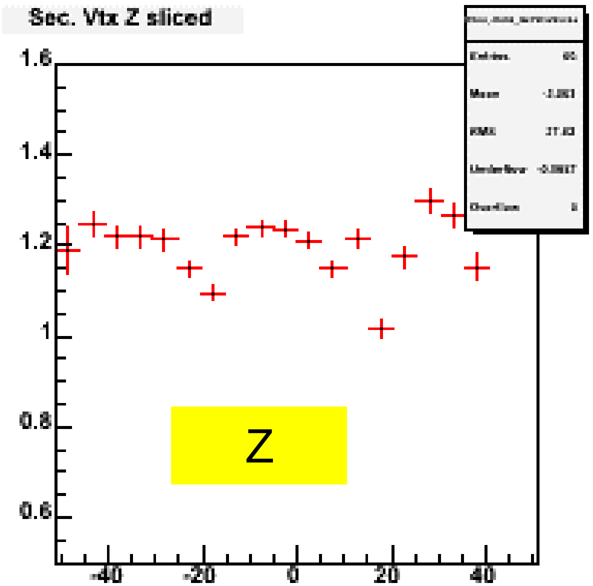
- We expect some variation as a function of Z (for instance, because of detector structure)
- Ct dependence?
- All variations well within ±10% when integrated over kinematics

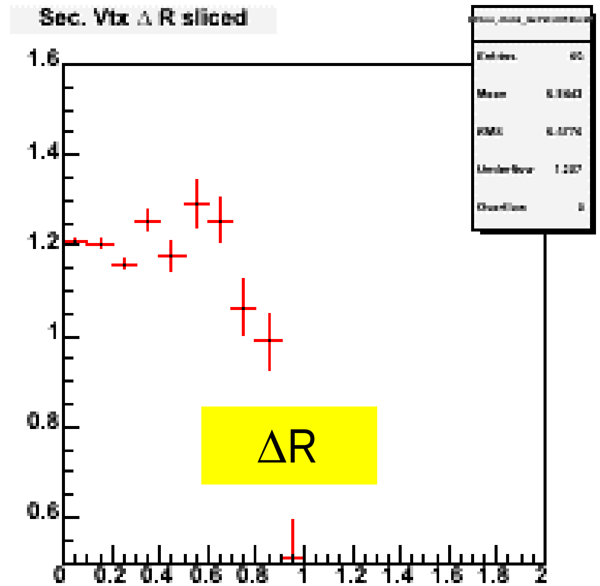


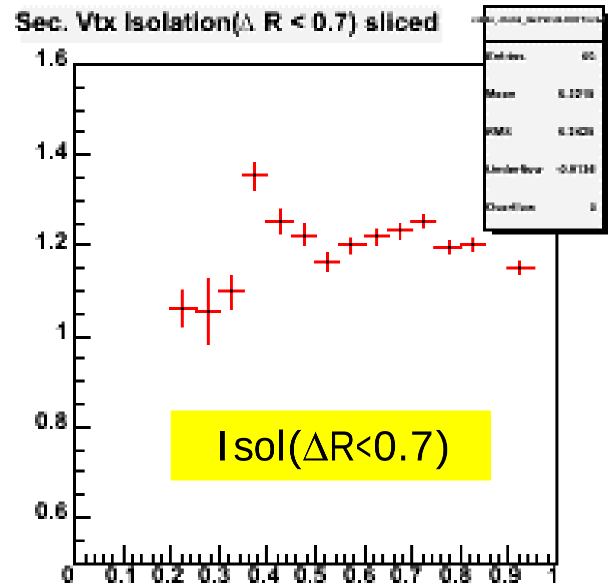


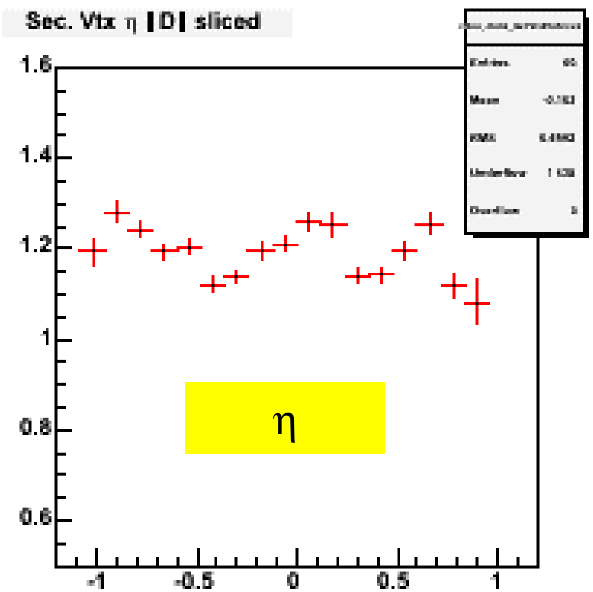


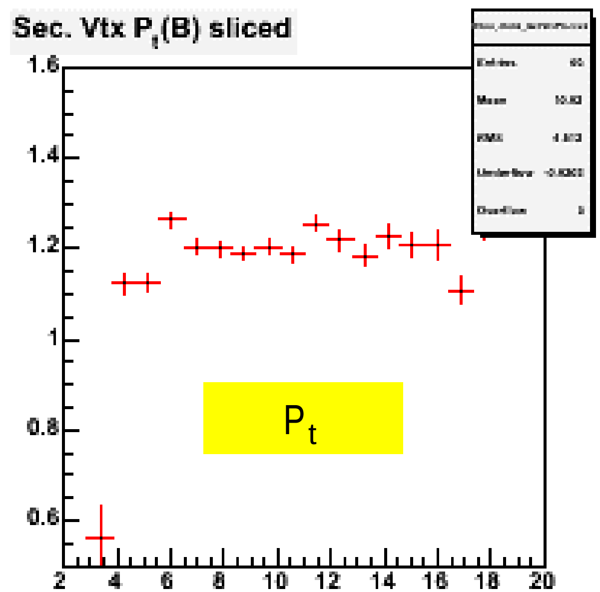
SV scale factor: details (à la CDF7500)





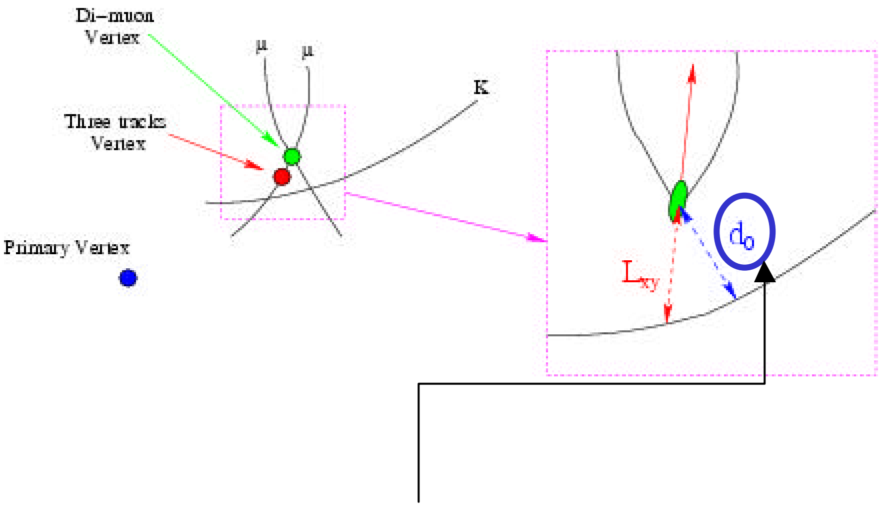




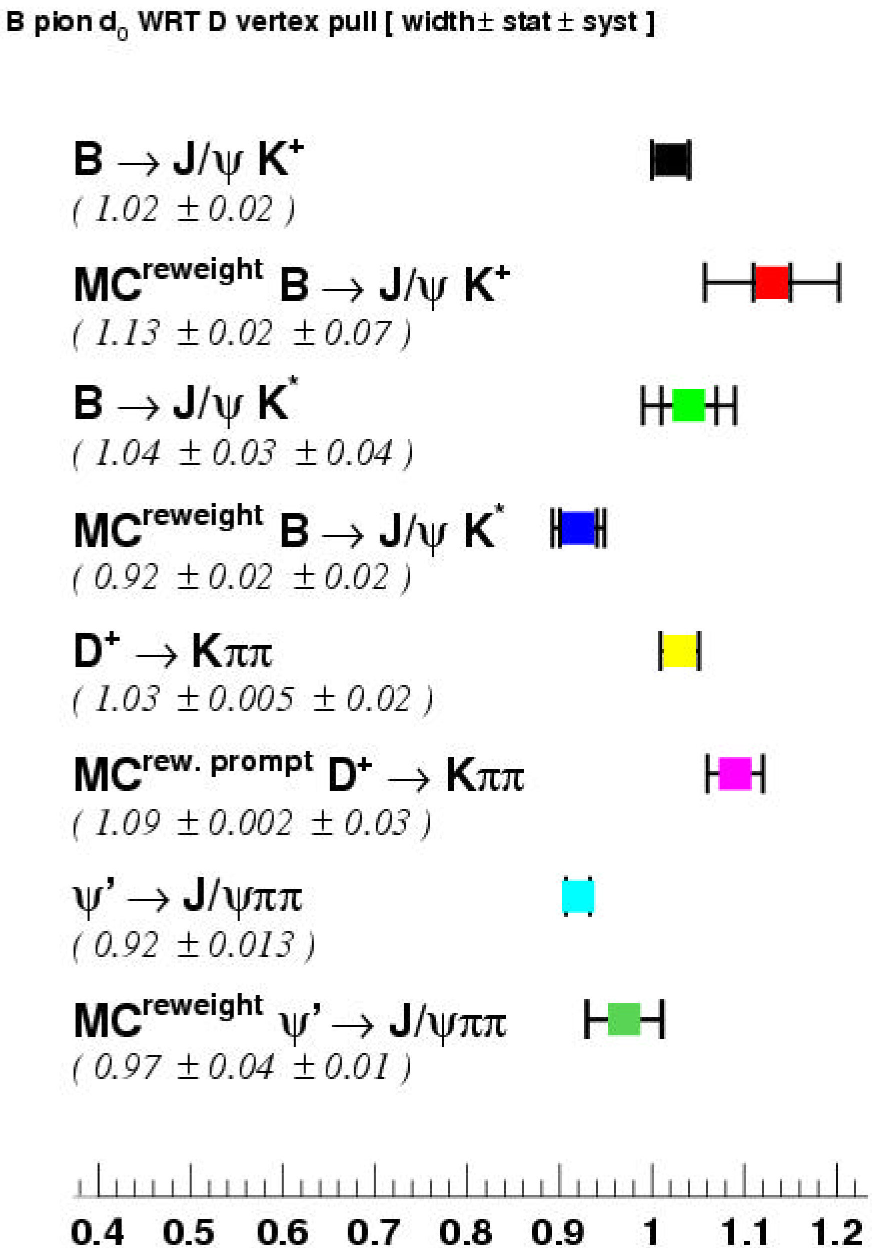


Non-statistical fluctuations dominated by fit model!

“N-1” d_0: a cross check!



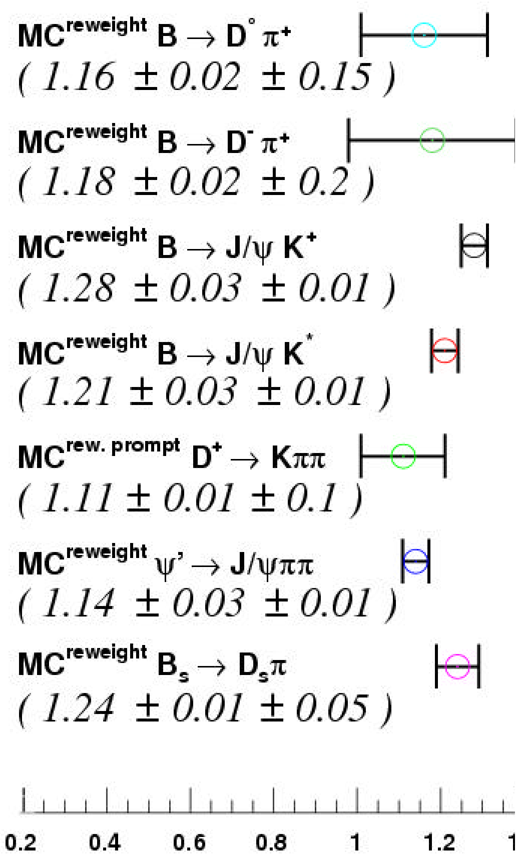
- Compute also d_0 pulls for the various samples
- Compare to MC evaluation
- Pretty good agreement here as well!
- Good job with the realistic simulation+reweighting!



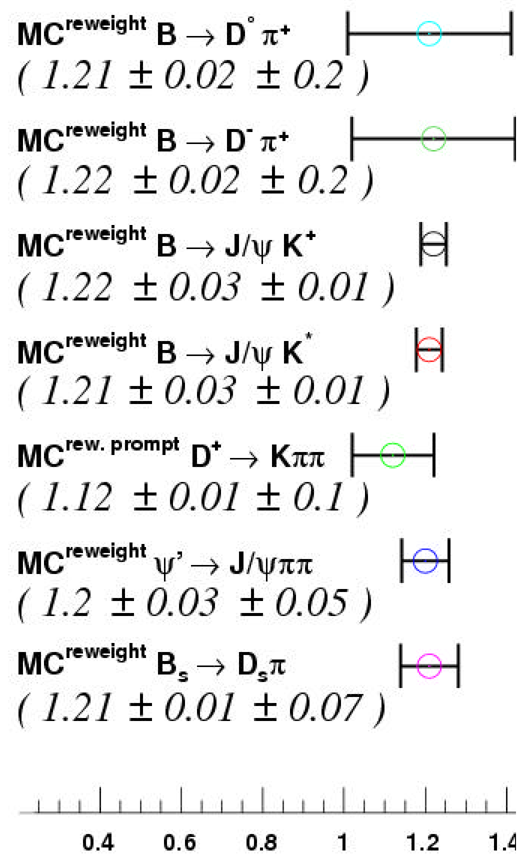
SV scale factor from MC

Now that we know to what extent we can rely on MC, let's look at reconstructed-truth!

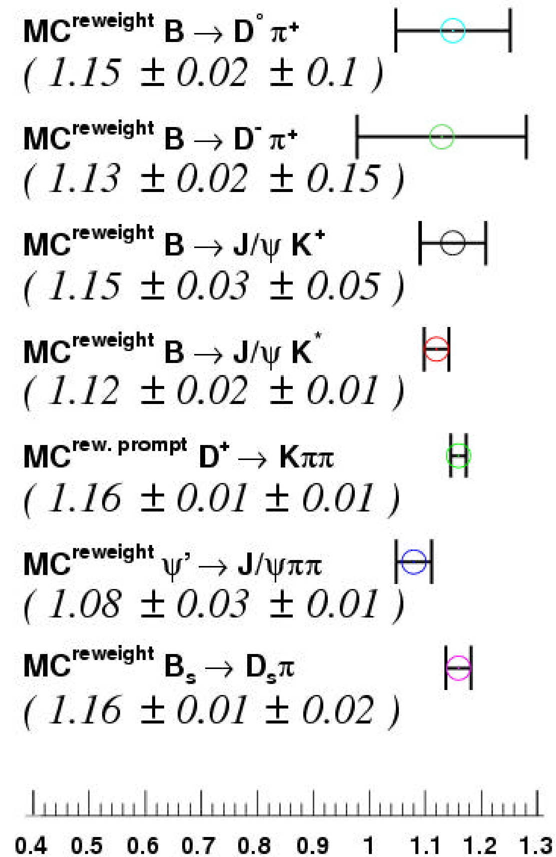
$SV_{reco}-Sv_{truth}$: X



$SV_{reco}-Sv_{truth}$: Y



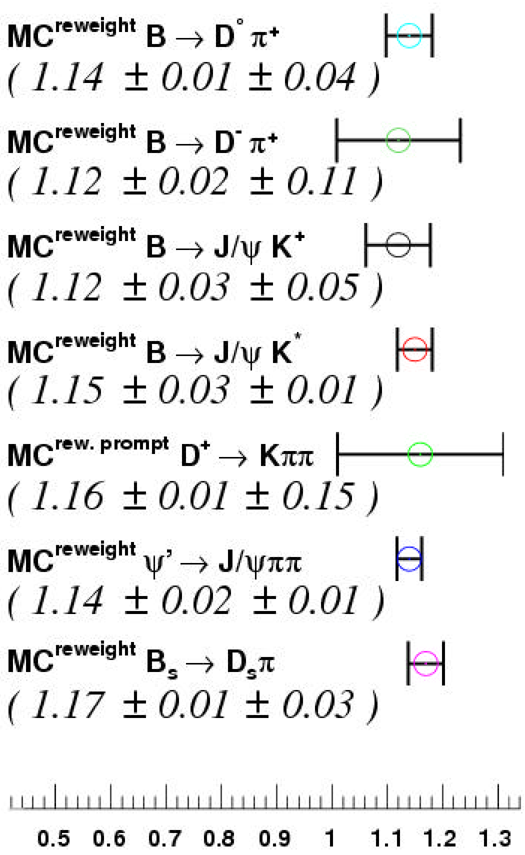
$SV_{reco}-Sv_{truth}$: Z



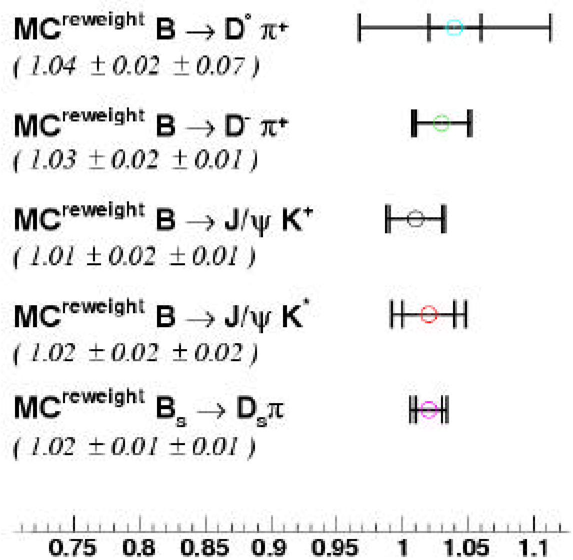
SV scale factor from MC

...projected along P_t, and broken down into PV and SV contribution:

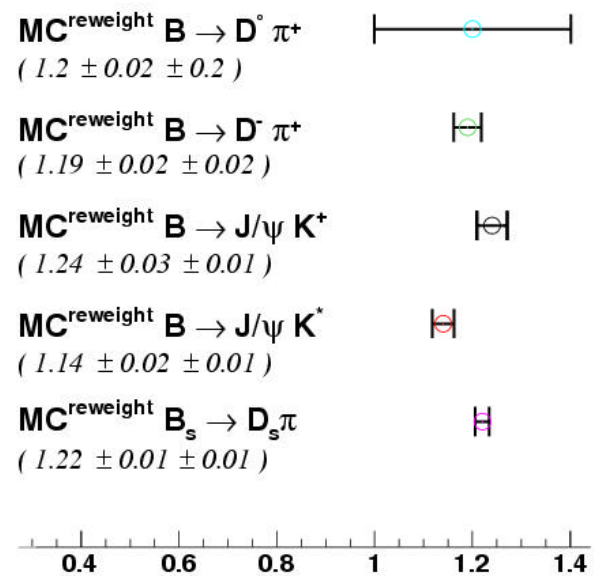
L_{xy}^{reco}-L_{xy}^{truth}



L_{xy}^{reco}-L_{xy}^{truth}: PV



L_{xy}^{reco}-L_{xy}^{truth}: SV



- Amazingly stable and consistent with X, Y and Z!
- Variations well within 10%

SV Pull Strategy

- "N-1" d_0 and L_{xy} validate montecarlo
- Dependencies studied in "N-1" d_0/L_{xy} are mostly due to choice of variables (to be confirmed by last bullet!)
- MC predicts a SV scale factor of 1.2±10%
- Before blessing: dependencies of MC scale factor