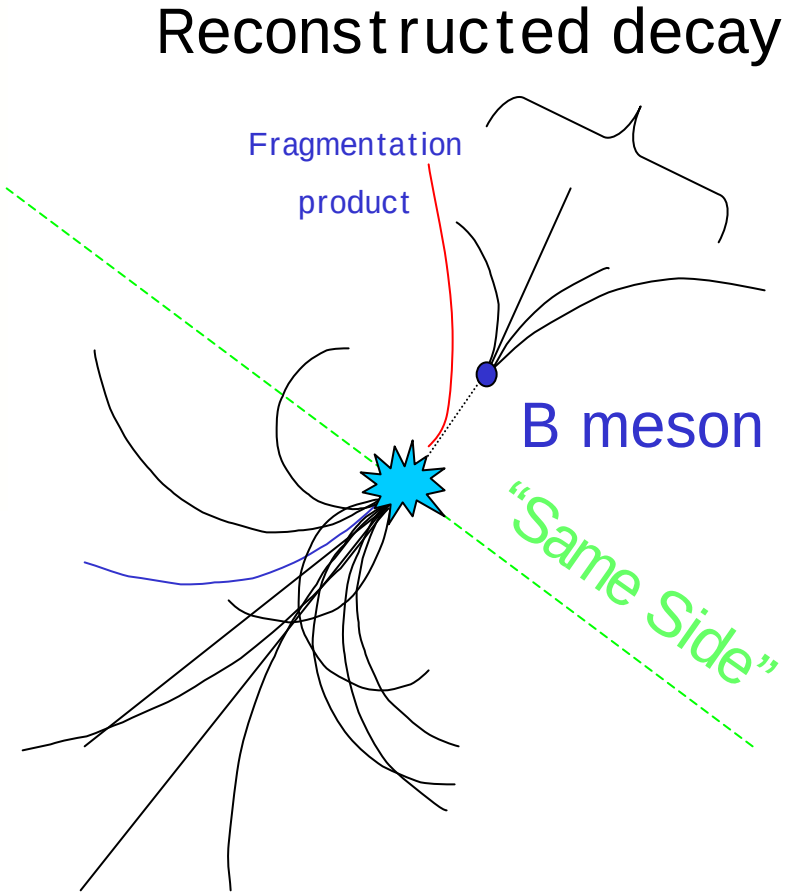
Flavor Tagging

what is going on, is there room to contribute?
Where?

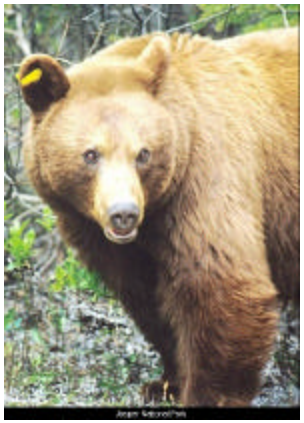
Alessandro Cerri, LBNL

$B_s \to D_s^- \pi^+ : \epsilon D^2$	
Same-Side Kaon	4.2%
μ tag	1.0%
e tag	0.7%
Jet Charge	3.0%
Opp.-Side Kaon	2.4%
Total (correl. small)	11.3%



Tagging

Barry Wicklund, Matthew Jones, Denys Usynin, Joe Kroll, Vivek Tiwari, Gavril Giurgiu, Guillelmo Gomez-Ceballos, Sasha Rakitin, Ilya Kravchenko, Ivan Vila, Alberto Ruiz, Jonatan Piedra, Marcin Wolter, Nuno Leonardo, Tania Moulik

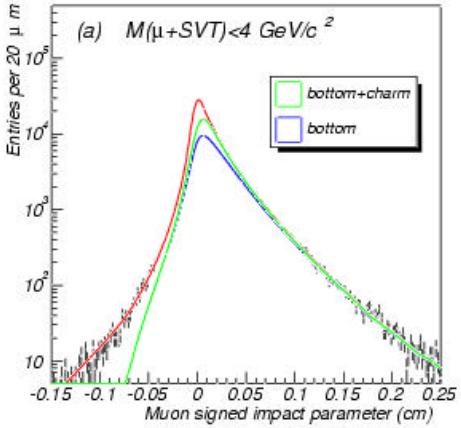


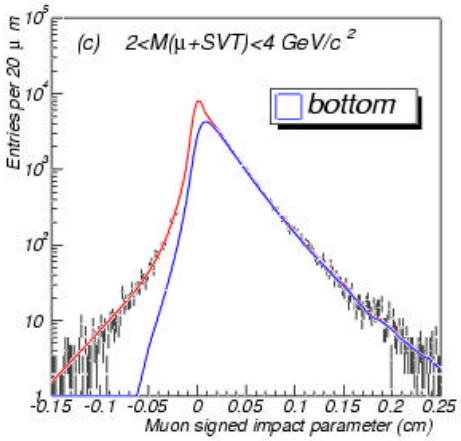
- To some degree, each of these can be developed and checked on the semileptonic sample:
  - Soft muon
  - Soft electron
  - Jet Charge
  - OSK
  - Same Side
- We have blessed results for:
  - Soft muon
  - SST
- SeT is still almost there
- JQT: optimized cuts. Still struggling with MC
- First tagger tests ran on $J/\Psi K$ and $D^0\pi$
- OSK still very naïve

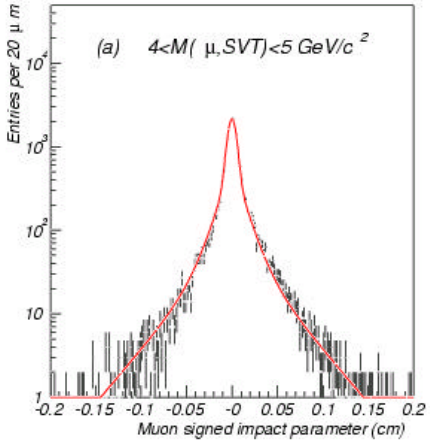
muon	raw D,%	ϵ, %
IMU	43 ± 9	0.18 ± 0.02
CMX	22 ± 5	0.59 ± 0.03
CMU only	13 ± 4	1.20 ± 0.05
CMP only	20 ± 7	0.36 ± 0.03
CMUP	27 ± 5	0.62 ± 0.03
Any	20.2 ± 2.5	2.92 ± 0.07

Sample Composition

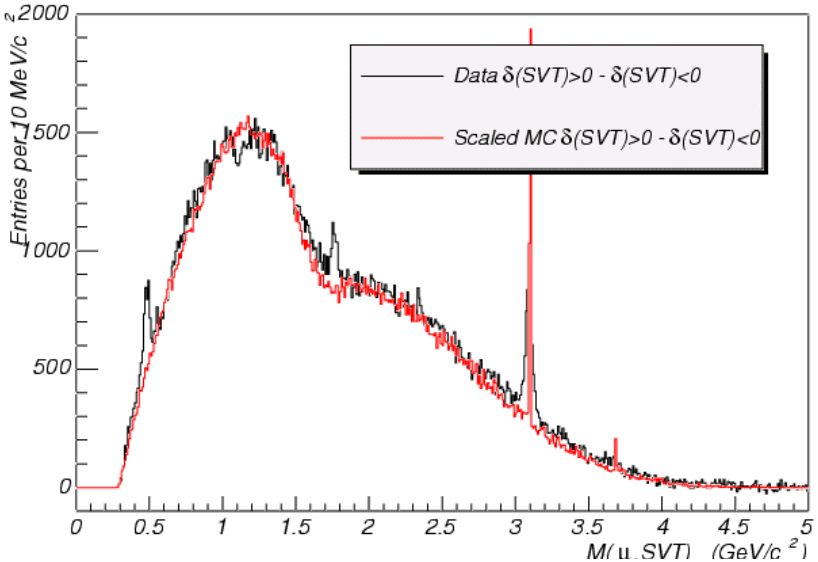
M. Jones, J. Kroll, A. Wicklund, D. Usynin







- Starting point for tagging studies: know your sample (how much b? → effective dilution)
- Use signed lepton d_0
- Take cc and bb model from MC templates
- Residual background model from [4,5] GeV region + prompt component
- Simultaneous fit:



component	$\mu + SVT$ $0-4$ GeV$/c^2$
$b \to \ell$	3290 ± 21 pb
$c \to \ell$	1234 ± 23
prompt	1018 ± 50
symmetric	382 ± 26

$$D_{\rm sub} = \begin{cases} 0.641 \pm 0.002\ ({\rm stat})^{+0.014}_{-0.023}\ ({\rm syst}) & \mu + SVT \\ 0.641 \pm 0.002\ ({\rm stat})^{+0.022}_{-0.037}\ ({\rm syst}) & e + SVT \end{cases}$$

Prompt charm pollution

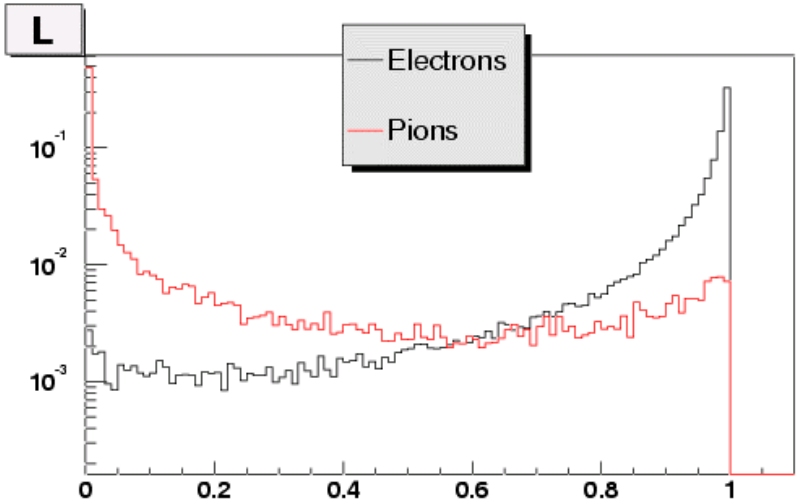
- Lifetime riddle tells us that:
  - Background is responsible
    - It has a resonant structure in the D mass
    - Has significantly shorter lifetime source than B
    - Not unlikely that l is fake a significant fraction of the times
  - As is, not good for tagging!
  - We can remove this background in a very easy way:

$$L_{xy} > 500\mu m$$

SeT

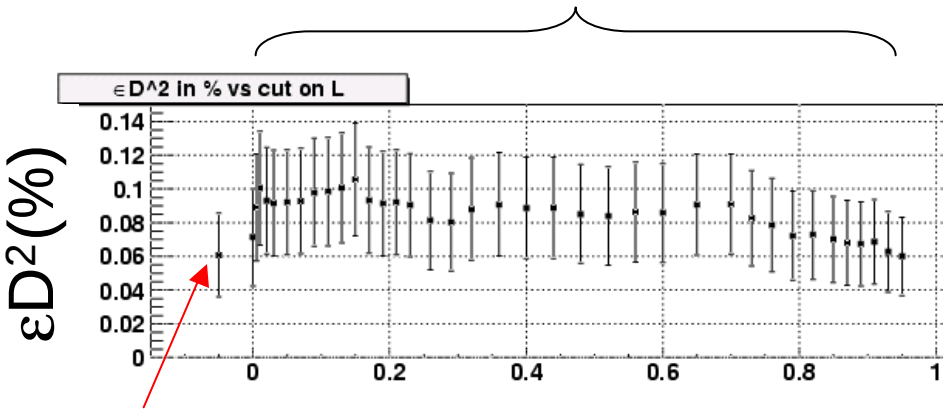
V. Tiwari, G. Giurgiu, M. Paulini, J. Russ, B. Wicklund, T. Moulik

- Two approaches so far:
  - Cut on electron ID
  - Build a likelihood and weight
- Improve efficiency
- Exploit the full rejection power of eid



- Efficiency for Electrons and Fakes

Likelihhod based, vs L lower cut



"Cut based"

X (L≥x)

$L \geq$	$\epsilon_\pi(\%)$	$\epsilon_e(\%)$	ϵ_e/ϵ_π
0.01	48	100	2.1
0.05	38	99	2.6
0.10	33	99	3.0
0.15	28	98	3.5
0.20	26	97	3.7
0.50	16	94	5.9
0.70	11	89	8.1
0.90	5	75	15.0

Table 1: Efficiencies of the cuts on L for pure electrons and pions.

L-based SeT performance (cont'd)

V. Tiwari, G. Giurgiu, M. Paulini, J. Russ, B. Wicklund, T. Moulik

- Binning in $p_T{}^{rel}$
  - Choose the cut on likelihood, $L \geq 0.15$ and bin in $p_T{}^{rel}$.

$p_T{}^{rel}$	OS/SS	$\epsilon(\%)$	$D(\%)$	$\epsilon D^2(\%)$
0.0	91/59	0.251 ± 0.025	21.33 ± 10.03	0.011 ± 0.011
0.0-0.4	55/22	0.129 ± 0.021	42.86 ± 17.26	0.024 ± 0.019
0.4-0.7	70/66	0.227 ± 0.025	02.94 ± 10.86	0.000 ± 0.001
0.7-1.0	78/60	0.230 ± 0.024	13.04 ± 10.70	0.004 ± 0.006
1.0-1.5	122/56	0.297 ± 0.024	37.08 ± 09.07	0.041 ± 0.020
1.5-2.0	77/28	0.175 ± 0.020	46.67 ± 10.64	0.038 ± 0.018
> 2.0	61/28	0.149 ± 0.020	37.08 ± 12.85	0.020 ± 0.014
Sum	554/319	1.458 ± 0.062		0.138 ± 0.038
Avg	554/319	1.458 ± 0.062	26.92 ± 04.21	0.106 ± 0.033
Cuts	318/183	0.837 ± 0.046	26.95 ± 05.46	0.061 ± 0.025

Table 2: ϵ, D and ϵD^2 in $\%$ after binning in $p_T{}^{rel}$ with the cut L ≥ 0.15 for the 8 variables case. Also shown are the average numbers from the likelihood and the cut-based approaches without binning in $p_T{}^{rel}$.

- The total raw ϵD^2 after binning in $p_T{}^{rel} = 0.180 \pm 0.043$.
- Correcting for trigger side dilution and sequential decays using $D_{sub} = 0.6412 \pm 0.0015$, we get $\epsilon D^2 = 0.438 \pm 0.105$ $\%$ for a total efficiency, $\epsilon = 1.927 \pm 0.072$ $\%$.
- Run I number from CDF note 3809, corrected $\epsilon D^2 = 0.34 \pm 0.08$ $\%$ (with dE/dx).

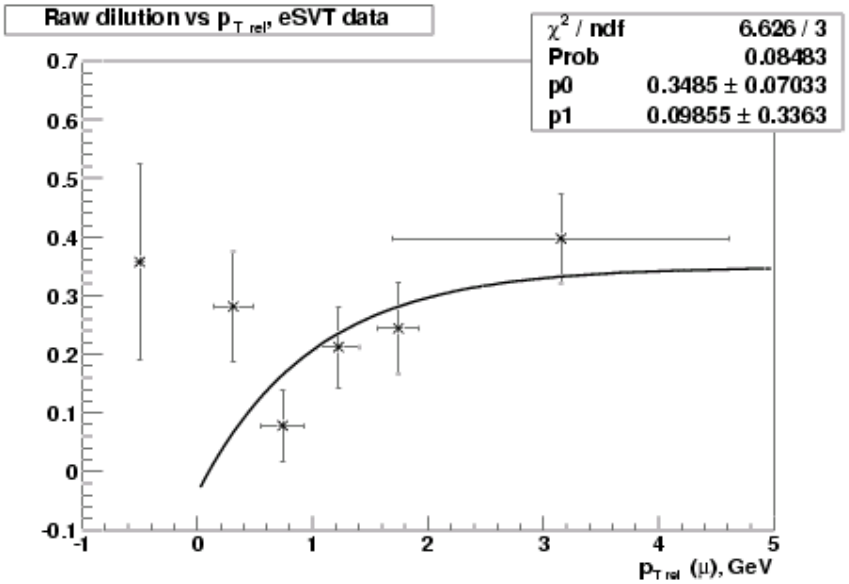
Please note:

There are several other very nice works in progress!

SμT

M. Jones, J. Kroll, A. Wicklund, D. Usynin V. Tiwari, G. Giurgiu, M. Paulini, J. Russ, B. Wicklund

- Compared to electrons:
  - Higher purity
  - Less handles to discriminate fakes
  - "Natural" fakes from decays in flight



muon	raw D,%	ϵ, %
IMU	30 ± 11	0.20 ± 0.02
CMX	26 ± 7	0.57 ± 0.04
CMU only	12 ± 6	0.89 ± 0.05
CMP only	15 ± 9	0.32 ± 0.03
CMUP	37 ± 6	0.54 ± 0.04
Any	22 ± 3	2.52 ± 0.08

muon	raw D,%	ϵ, %
IMU	39 ± 9	0.23 ± 0.02
CMX	21 ± 6	0.60 ± 0.04
CMU only	9 ± 5	0.90 ± 0.05
CMP only	16 ± 8	0.33 ± 0.03
CMUP	25 ± 5	0.59 ± 0.03
Any	19 ± 3	2.62 ± 0.08

A likelihood-based approach is being developed (?)

Comparisons

Blessed:

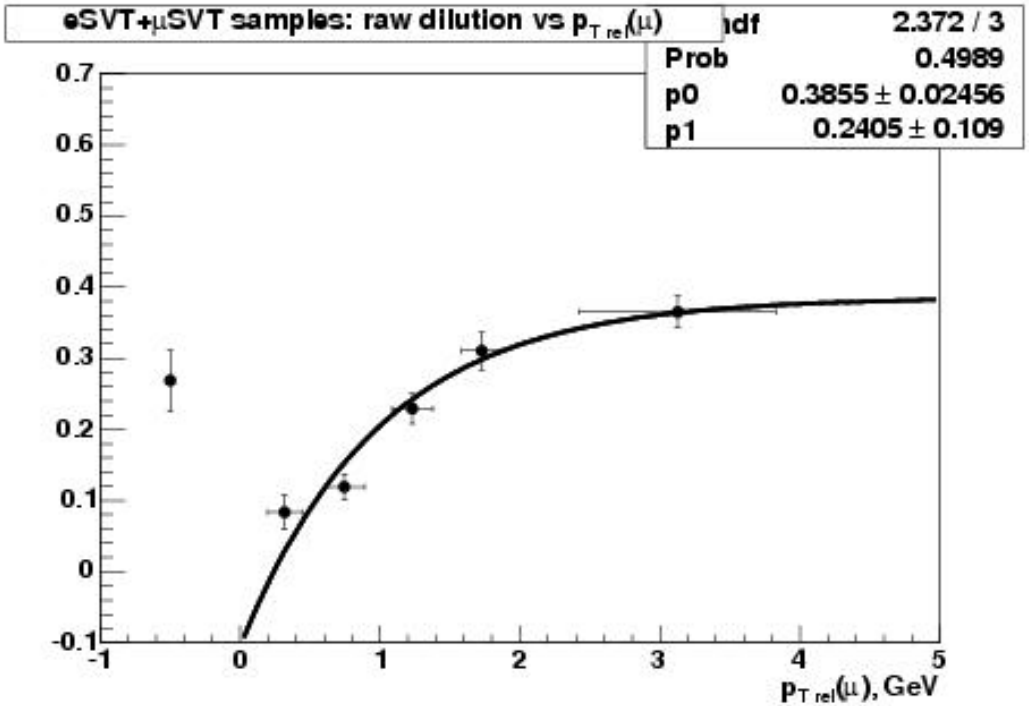
$$\epsilon D^2 = \begin{cases} 0.735 \pm 0.122\ \% & \mu + SVT \\ 0.583 \pm 0.134\ \% & e + SVT \end{cases}$$

Updated:

$$\epsilon D^2 = \begin{cases} 0.576 \pm 0.056\ \% & \mu + SVT \\ 0.515 \pm 0.061\ \% & e + SVT \end{cases}$$

Old 64pb run range, with 5.1 data:

$$\epsilon D^2 = \begin{cases} 0.680 \pm 0.092\ \% & \mu + SVT \\ 0.640 \pm 0.090\ \% & e + SVT \end{cases}$$

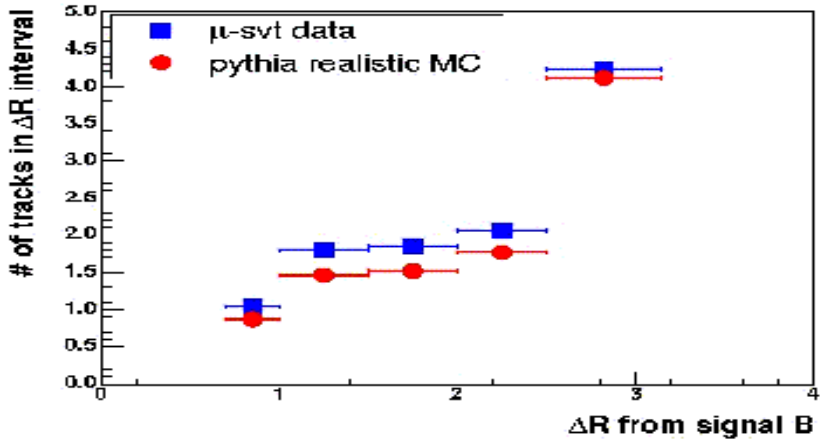


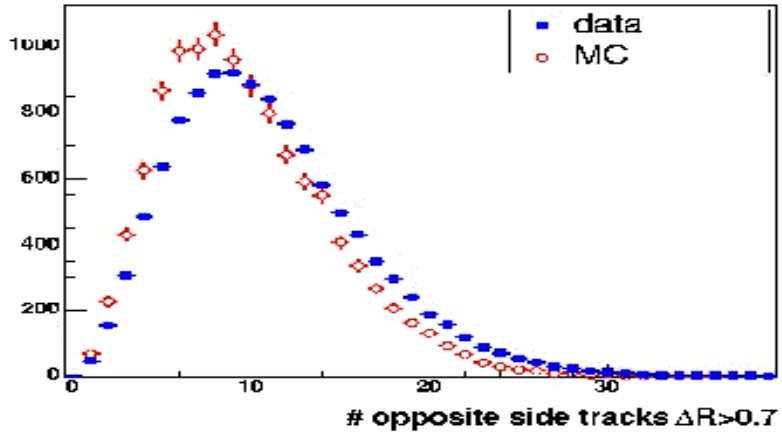
Run I: 0.584±0.082 % (M. Peters & co.)

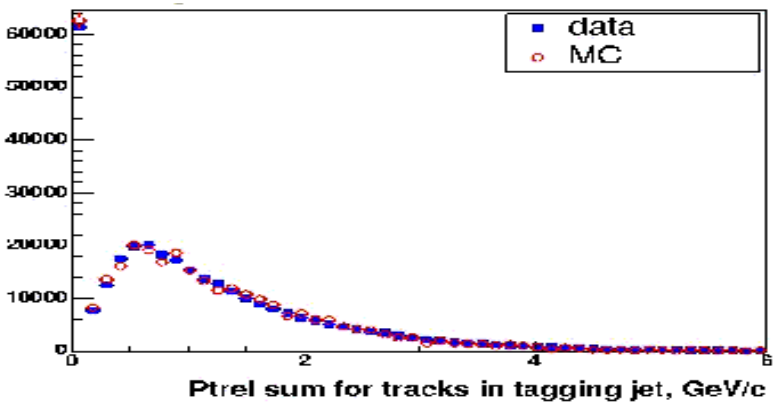
JQT

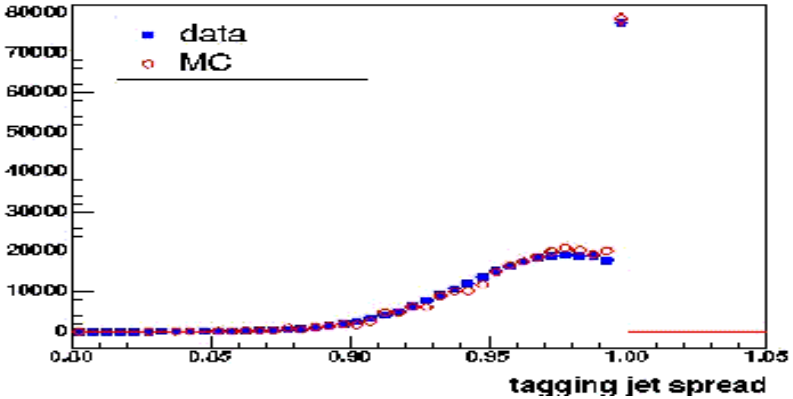
Ilya Kravchenko

- Exercising in a full-fledged data/MC comparison [ID^0]
- Still significant discrepancies in the montecarlo: needs tuning!









First Glance Performance:

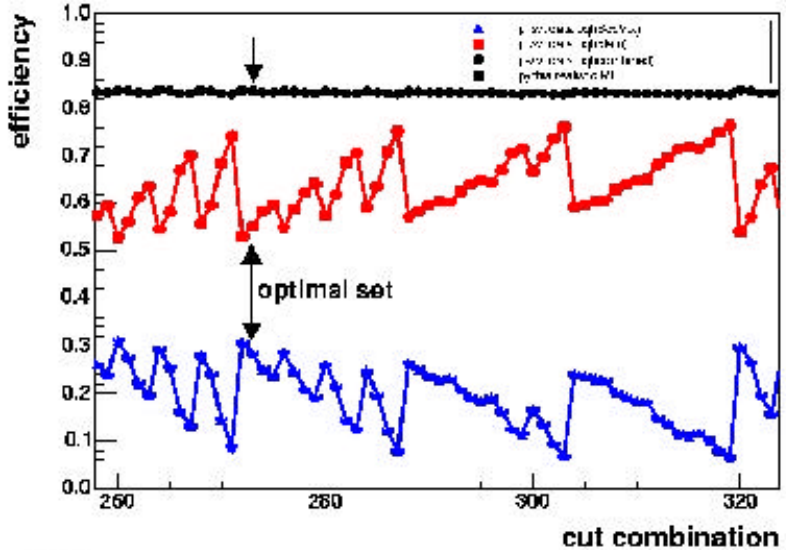
$\varepsilon \approx 65\%$

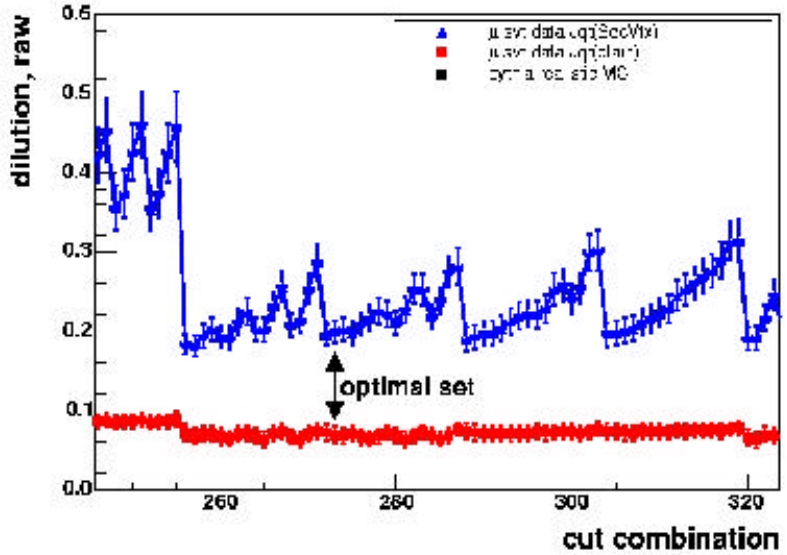
$D_{raw} \approx 4\%$

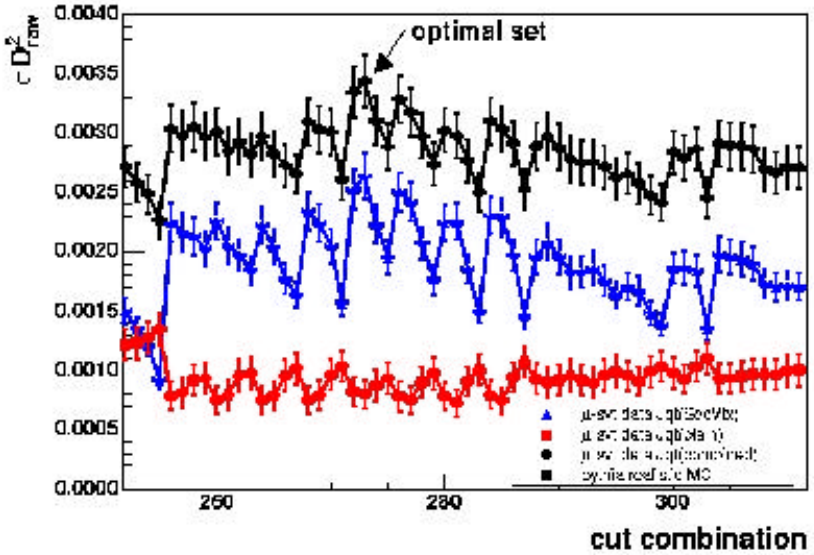
$\varepsilon D^2_{raw} \approx 0.11\%$

JQT tuning

- each point: a set of cuts
- full plot runs from 0 to 2559
- part with the best point shown
- optimal set: point 273
  - $dR_{jm} = 1.0$ $dR_{clm} = 0.7$
  - d0sigp1 = 0.0 d0sigp2 = 1.0
  - ptp1mx = 0.5 ptp2mx = 1.2
- notice: high SecVtx efficiency







JQT tuning: details

Tuned parameters:

- dR_{clm} = {0.7,0.9,1.2,1.5}
- dR_{jm} = {0.8,1.0,1.2,1.5}
- d0sigp1={0.0,1.0,2.0,3.0}
- d0sigp2={0.0,1.0,2.0,3.0}
- ptp1mx={0.5,1.2,2.0,3.0}
- ptp2mx={0.5,1.2,2.0,3.0}

Scan strategy:

- try all points of 6D grid
- keep dRclm<dRjm
- total 2560 sets to explore

Fixed parameters of JQT:

- pttrack 0.4 GeV min
- ptseed 1.0 GeV min
- dR_{iso} 0.7
- ptcutp1 0.4 GeV min
- ptcutp2 0.4 GeV min
- atcutp1 3.0 max
- Lxy 3.0 min
- p1ptupgradep2 false
- 3D vertexing false

Run I comparison

Run I numbers, again, on 8 GeV lepton + vertex:

- average D (cdf4847): $\epsilon D^2 = 0.46 \pm 0.09\%$
- use $D(Q_{jet})$(cdf4315): $\epsilon D^2 = 0.78 \pm 0.15\%$

More details on Run II numbers with Run I cuts:

- no cut on $P_t(\mu)$

tag type	ϵ, %	, D, %	ϵD^2, %
events with SecVtx jet	3.4	20.8±1.4	0.145±0.019
events with no SecVtx jet	27.1	7.2±0.5	0.139±0.019
combined	30.5	—	0.284±0.027

- with cut $P_t(\mu) > 8GeV$

tag type	ϵ, %	, D, %	ϵD^2, %
events with SecVtx jet	4.9	25.6±2.3	0.319±0.064
events with no SecVtx jet	34.2	6.3±1.0	0.136±0.042
combined	39.1	—	0.455±0.077

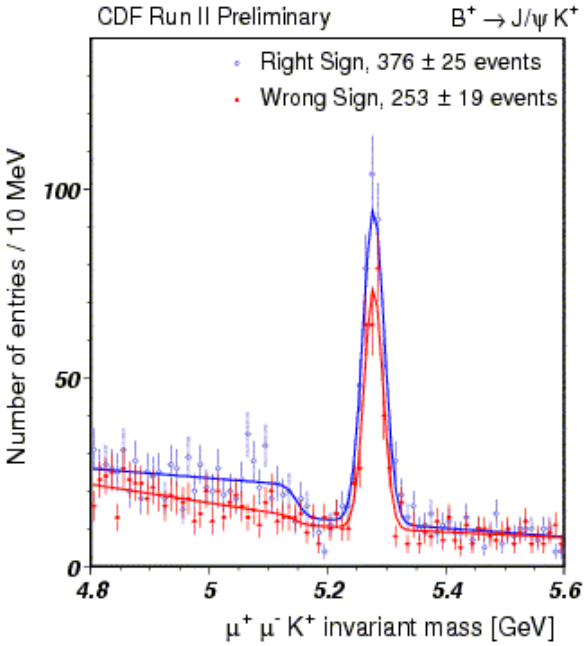
JQT 2004

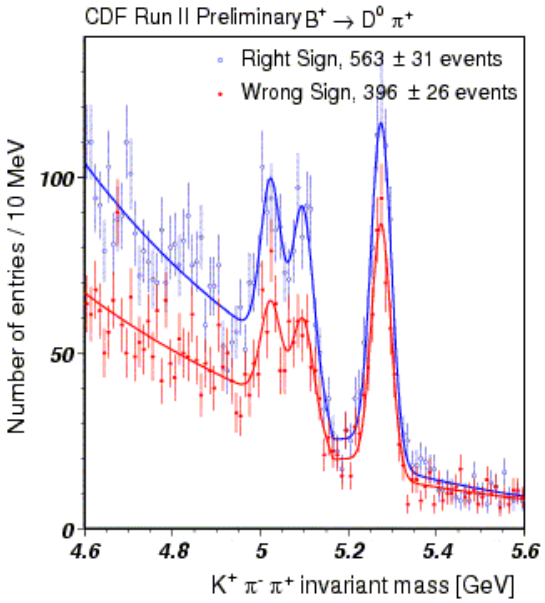
- Got in the phase of “systematic” studies
- Still open issues:
  - X3 discrepancy in D predictions between data & MC
  - Revise SecVtx tuning?
  - How much is L00 helping?
- My favorite topics (I.e. my interests):
  - “Refurbished” vertexing
  - Merging with PID
    - Naïve, single track
    - Full blown likelihood-based (rewarding but tough!)

SST

Gerry Bauer, Guillelmo Gomez-Ceballos, Ilya Kravcenko,
Nuno Leonardo, Cristoph Paus, Jonatan Piedra,
Sasha Rakitin, Alberto Ruiz, Ivan Vila

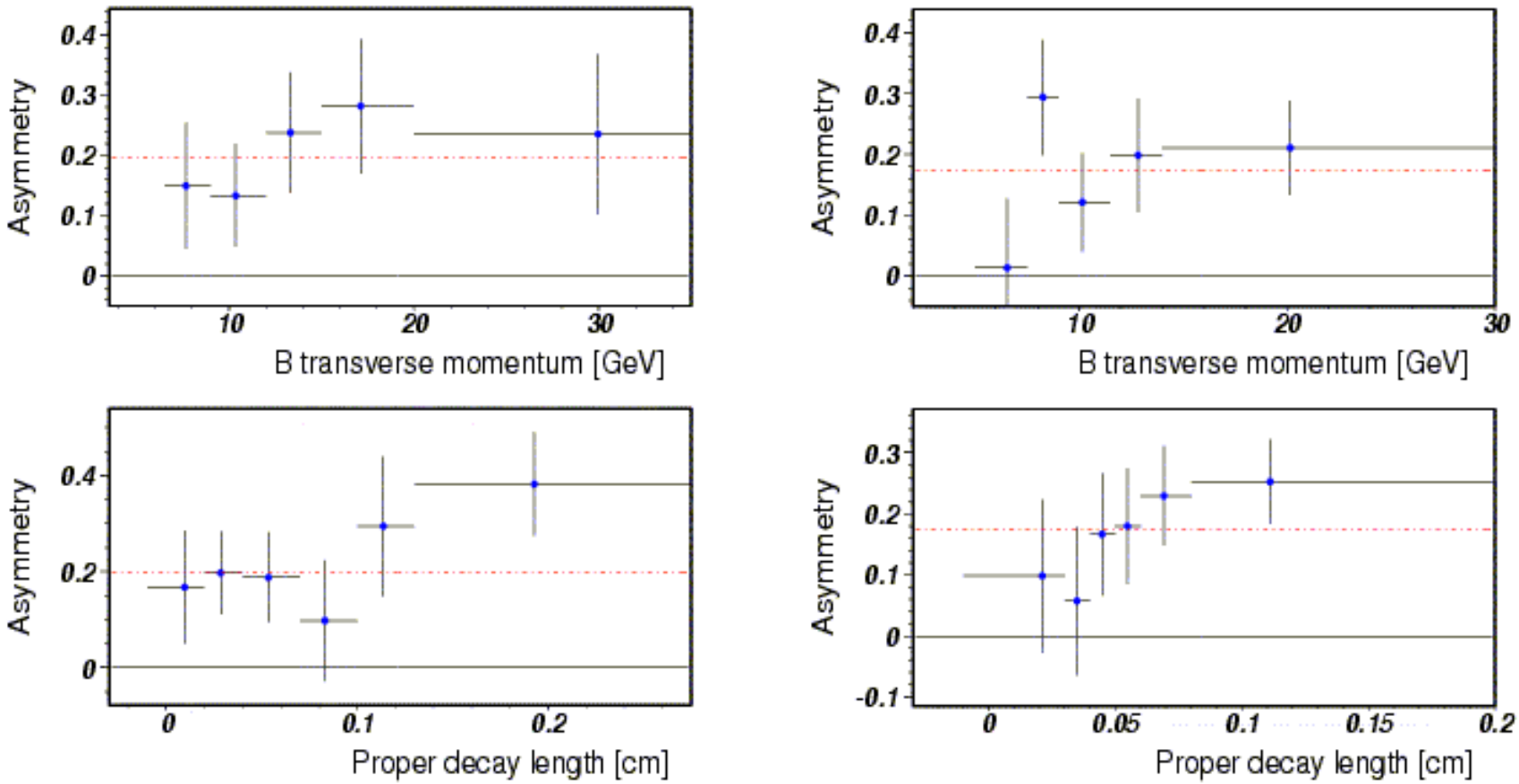
- Run I-like algorithm has been implemented:
  - $\Delta R<0.7$, $Pt>0.4$
  - $|d_0/\sigma|<3.0$
  - Minimum P_t^{rel}
- Results are checked on two samples:
  - $B^+ \rightarrow \psi K^+$
  - $B^+ \rightarrow D^0 \pi^+$
- Encouraging results, working on a large statistics study (e.g. lD^0)





SST (cont'd)

$B^+ \to J/\psi K^+$ $\qquad$ $B^+ \to D^0\pi^+$

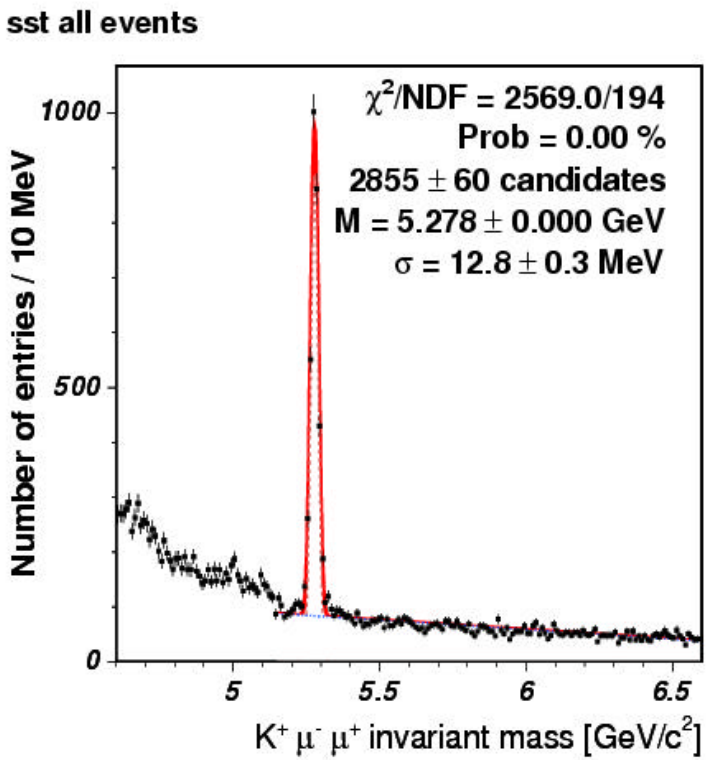


	N_{RS}	N_{WS}	N_{NT}	ϵ	D	ϵD^2
$J/\psi K^+$	376 ± 25	253 ± 19	379 ± 23	62.4 ± 1.8	19.7 ± 4.9	2.4 ± 1.2
$D^0\pi^+$	563 ± 31	396 ± 26	588 ± 27	62.0 ± 1.5	17.4 ± 4.1	1.9 ± 0.9

SST 2004

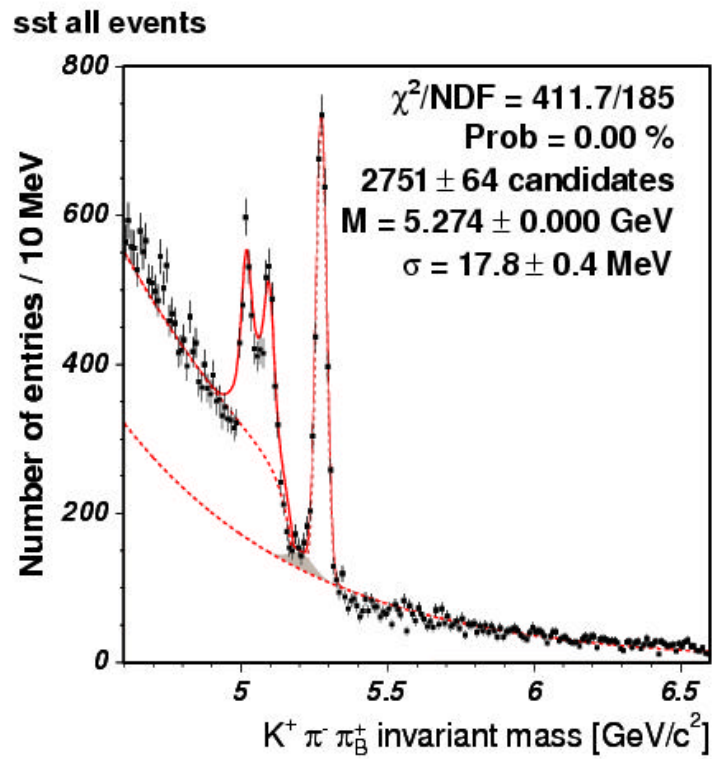
$B^+ \to J/\psi K^+$

- $N(J/\psi K^+) = 2855 \pm 60$



$B^+ \to \bar{D}^0\pi^+$

- $N(\bar{D}^0\pi^+) = 2751 \pm 64$



Decay	ϵ (%)	D (%)	ϵD^2 (%)
$B^+ \to J/\psi K^+$	62.5 ± 0.9	19.0 ± 2.3	2.3 ± 0.6
$B^+ \to \bar{D}^0\pi^+$	63.0 ± 0.9	20.8 ± 2.4	2.7 ± 0.6

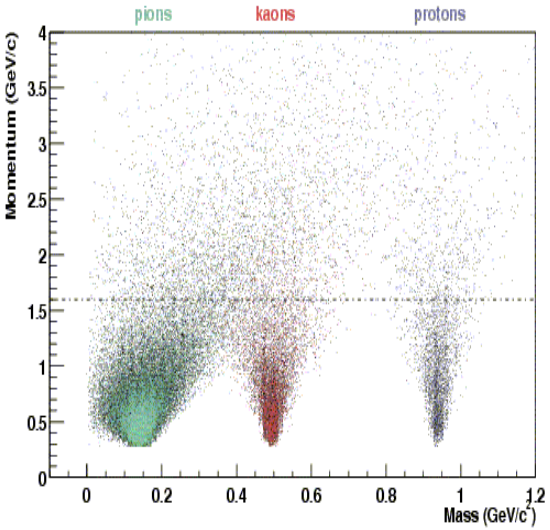
SST 2004 cont'd

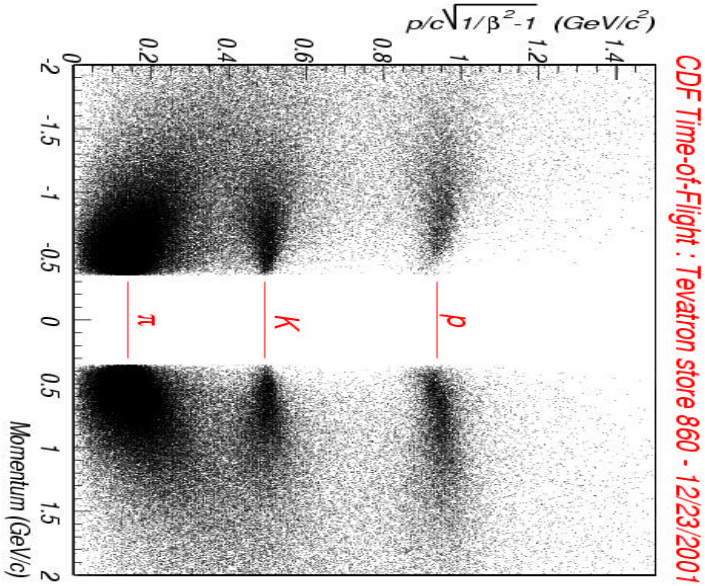
- Reasonable agreement with Run I
- Lacking a more systematic approach than just "cut and try":
  - MC tuning
  - Cut optimization
  - Tagger calibration
    - Benchmark on semileptonics
    - Compare with TTT
    - Understand differences (trigger biases?)
  - Combine with PID?

OSK: TOF

J. Piedra, A. Ruiz, I. Vila, M. Wolter and Ch. Paus

	ε (%)	D (%)	εD² (%)
100% eff., 110ps	12.2±0.3	30.6±2.9	1.14±0.25
GEANT 110ps	10±0.3	28.4±3.2	0.81±0.21
GEANT, ε=0.8 t_0 truth	11.2±0.3	26.8±3.8	0.8±0.2
GEANT	11.2±0.3	23.9±3.0	0.64±0.18
GEANT 65% eff.	9.4±0.3	27.0±3.3	0.68±0.19





First naïve attempts on data:

$$\epsilon = 4.34 \pm 0.41\%$$

$$D = 17.43 \pm 9.43\%$$

$$\epsilon D^2 = 0.13 \pm 0.16\%$$

OSK 2004

- TOF reconstruction/simulation are getting better
- We need an effort:
  - Aggressive
  - Systematic
  - Goal-oriented
  - Quick and responsive
- My favorite direction: merging with smart vertexing and JQT (see JQT slide)

Beyond the Baseline

- "Same tags, new samples": tagging-enhanced samples:
  - Hadronic+TOF hit(track)
  - Hadronic+away side track
    - How soft?
    - Displaced?
    - TOF-tagged
    - Lepton?
  - Hadronic+same side track
    - How soft?
    - TOF-tagged?
  - Replace "hadronic" with anything, in principle
- "New tags"
  - Opposite side charm!
    - Ultra-low momentum tracking is crucial! ($D^* \rightarrow (K\pi)\pi^*$)
    - Also PID could help ($D^* \rightarrow (K\pi)\pi^*$)?

L1 already knows which XFT tracks have TOF hits!

Bring the information @ L2?

Tagging category	ε (%)	w(%)	Q (%)
Lepton	10.9 ± 0.3	8.9 ± 1.3	7.4 ± 0.5
Kaon	35.8 ± 0.5	17.6 ± 1.0	15.0 ± 0.9
NT1	7.8 ± 0.3	22.0 ± 2.1	2.5 ± 0.4
NT2	13.8 ± 0.3	35.1 ± 1.9	1.2 ± 0.3
ALL	68.4 ± 0.7		*26.1 ± 1.2*

Conclusions

$B_s \to D_s^- \pi^+ : \epsilon D^2$		
Same-Side Kaon	4.2%	0%
μ tag	1.0%	0.55%
e tag	0.7%	0.3%
Jet Charge	3.0%	0.4%
Opp.-Side Kaon	2.4%	0.13%
Total (correl. small)	11.3%	

YES!

Wondering if I am cheating? YES!

Where is the room?

- Overall:
  - So far effort concentrated on reproducing Run I results, can we go beyond?
    - Extended coverage
      - Standalone Si tracks
      - Plug detectors for leptons
    - Montecarlo tuning
      - Detector understanding
      - Improve physics modeling
    - Improved/Alternative taggers
      - OSK
      - SSK
      - “merged” taggers
    - The best tagger is without cuts