5.x Tracking

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for the Tracking group

Joint Physics Meeting

December 12, 2003

Overview

COT Upgrades

- Cosmic-based alignment
- Beam-based HL tracking
- Hit dropping
- Hit resolution change
- defTrack definition
- dE/dx
- t_0
- Simulation resolution

Inside-Out Algorithm

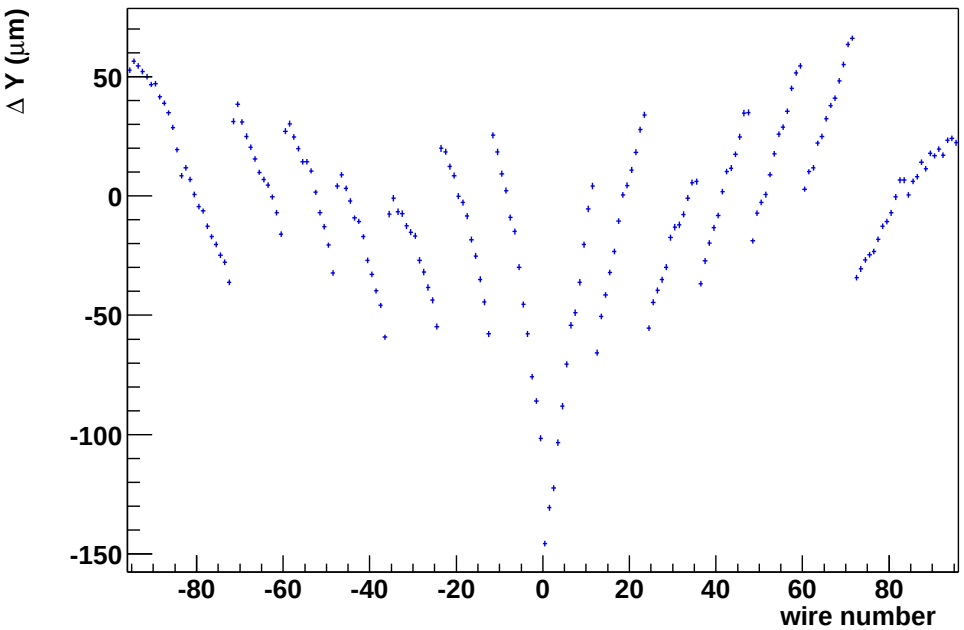
Silicon Upgrades

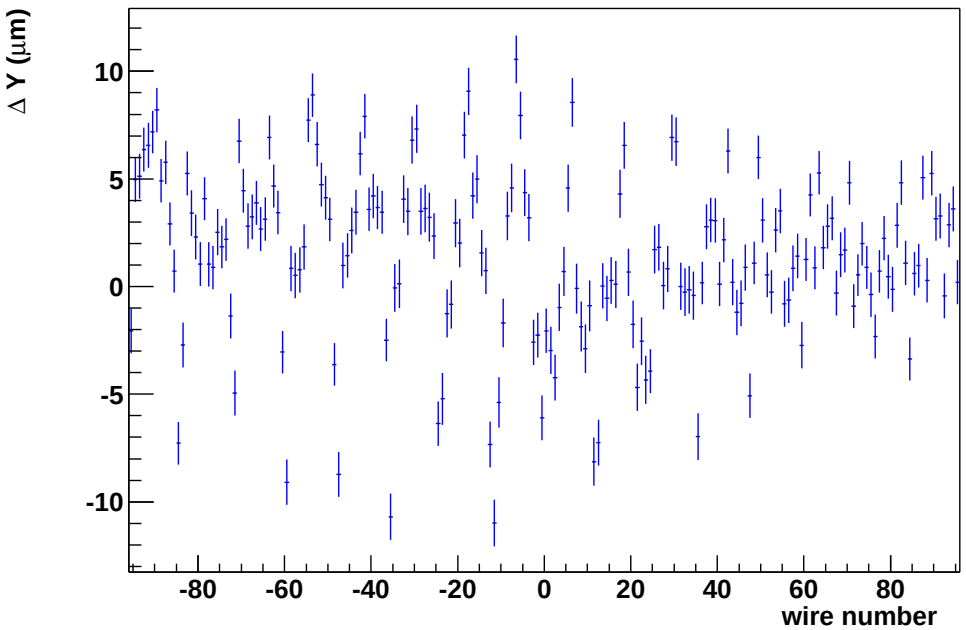
- Updated COT-based SVX, ISL, L00 alignments
- Expanded OI roads
- Phoenix tracking in production
- Parametric model default for simulation

Beyond 5.x

Cosmic-based Alignment

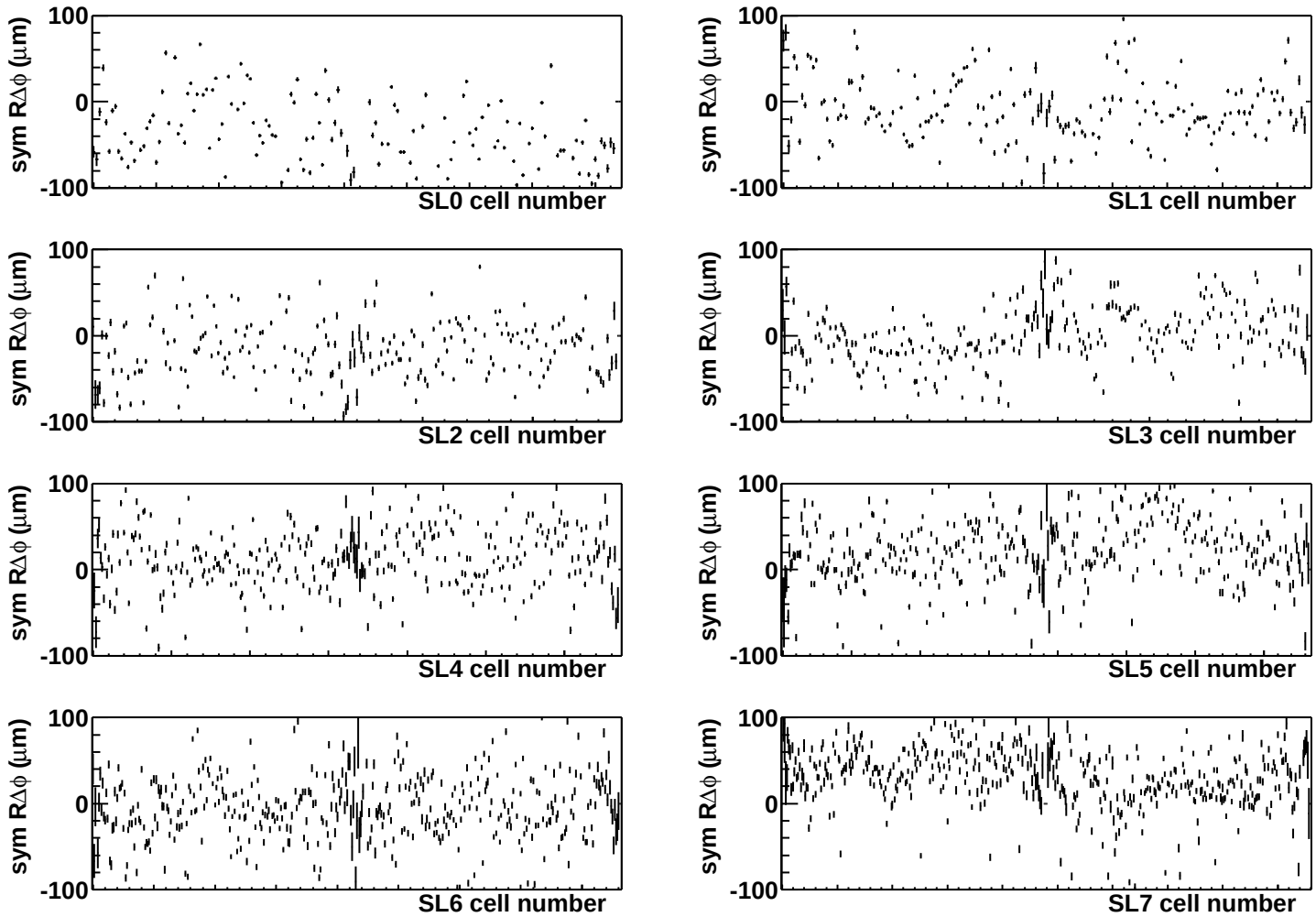
Use hit residuals from cosmic tracks to measure cell tilts, shifts (phi effects)
Incorporate best estimates of gravitational sag, electrostatic effects (z effects)
Cross-check with FEA analysis





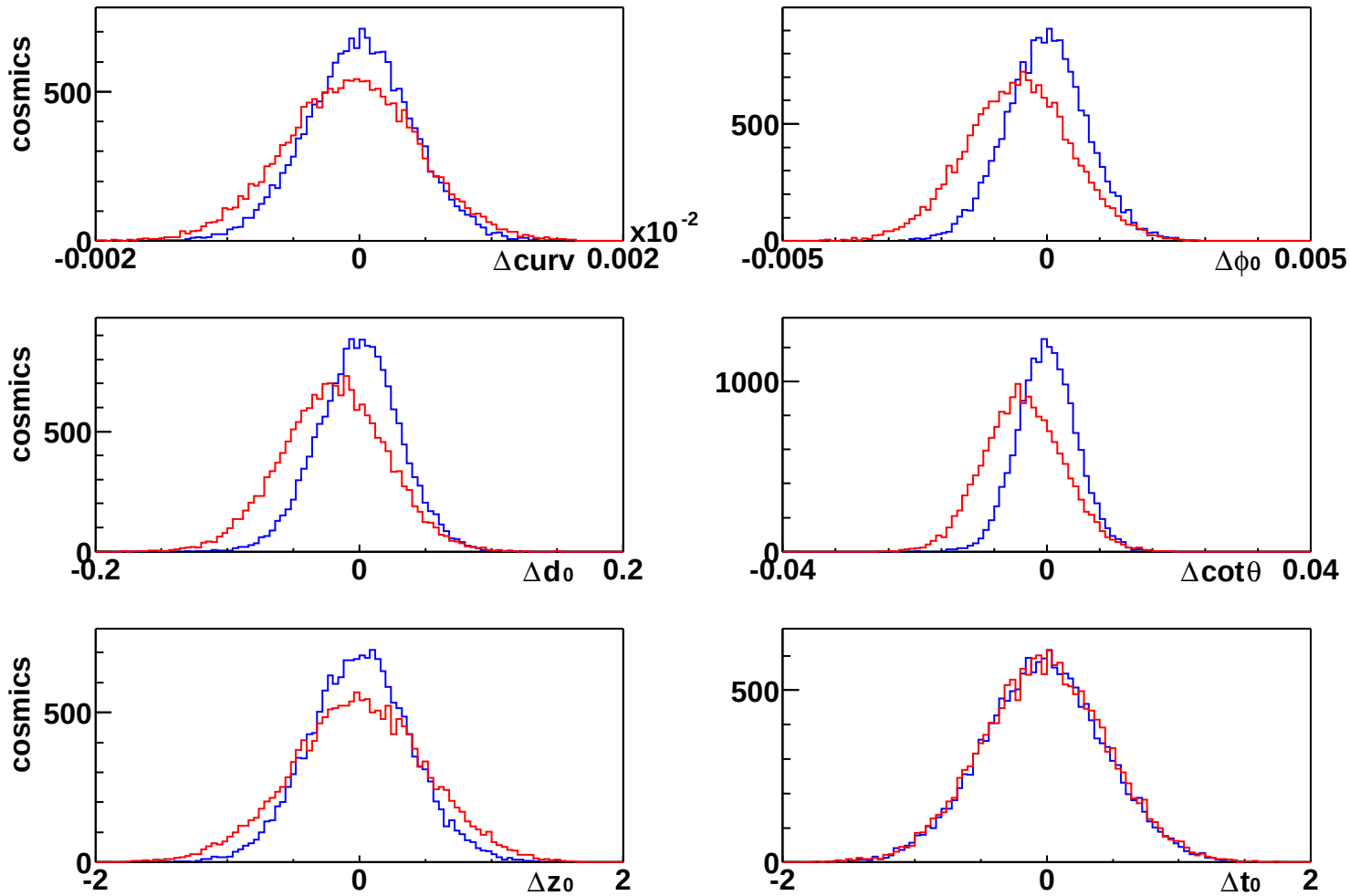
Cosmic-based Alignment

Cell shifts



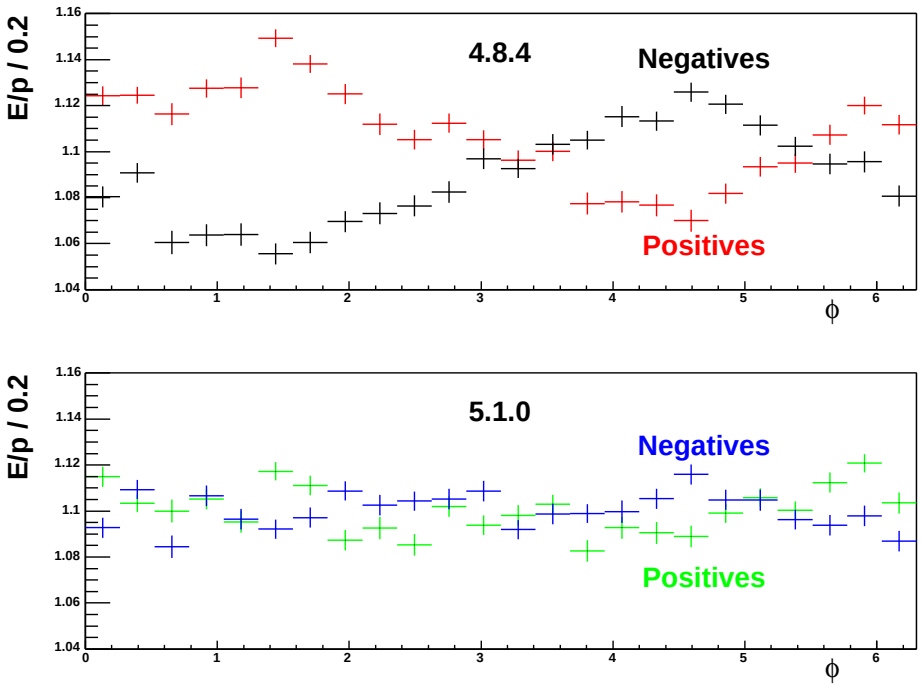
Cosmic-based Alignment

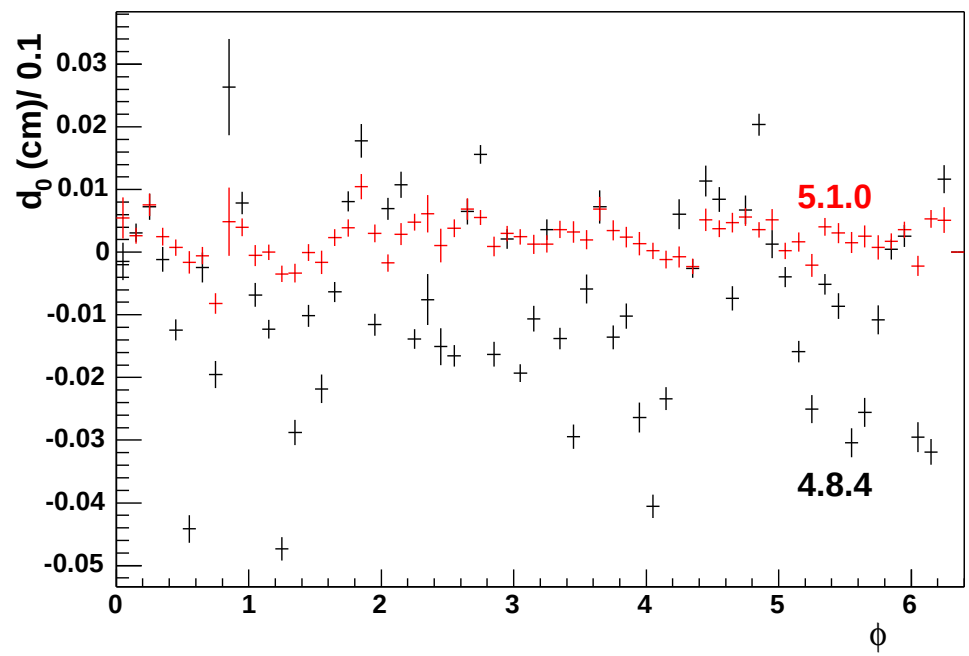
Difference between track parameters from incoming and outgoing cosmics
Alignment reduces bias and improves resolution (red: 4.x, blue: 5.x)



Cosmic-based Alignment

E/p versus ϕ from W electrons
d_0 versus ϕ from generic tracks





Ashutosh: Cosmic iterations
Aseet: FEA cross-check
Bob: Updated sag calculation, electrostatic interpretation
Ray, Lucio: Early studies

Beam-based HL Tracking

In 5.x, HL uses the COT beam position as a seed for axial pattern recognition

Small bias in d_0 measurement from using 0,0 as beam position

Comparison of SL (unbiased), HL seeded with -0.1035, 0.3967, and HL seeded with 0,0:

Algorithm	Beam x (μm)	Beam y (μm)	Beam x slope (μrad)	Beam y slope (μrad)
HL 0,0	-1955 $\pm$ 5	3965 $\pm$ 5	156 $\pm$ 23	383 $\pm$ 23
HL offset	-2121 $\pm$ 5	4540 $\pm$ 5	105 $\pm$ 23	412 $\pm$ 23
SL	-2261 $\pm$ 6	4612 $\pm$ 6	117 $\pm$ 25	496 $\pm$ 25

Beamline group (Karen, Joao, Andy, Alexey, ...): Beamlines in production
Peter W.: HL beam offset code
Ray: Validation of bias reduction

Hit Dropping

Drop hits after final fit; if new fit fails, restore original track

Ideal road (400 μm) determined using Monte Carlo $t\bar{t}$+3 min bias

Loosened to 600 μm to allow for pathological cases in data

Improved resolution demonstrated with data:

- 5% reduction in J/ψ width (7% with hit-adding, not default)

Resolution improvement in Monte Carlo:

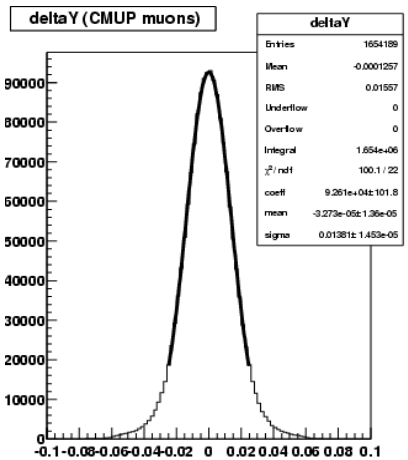
Method	c RMS (cm^{-1})	d_0 RMS (cm)	ϕ_0 RMS	z_0 RMS (cm)	$cot\theta$ RMS	eff.
4.8.x	4.12×10^{-5}	0.341	0.00640	3.75	0.0957	92.58%
5.1.x	3.51×10^{-5}	0.340	0.00633	3.64	0.0946	92.94%
5.1.x + add	3.39×10^{-5}	0.319	0.00602	3.59	0.0944	93.06%

Yimei

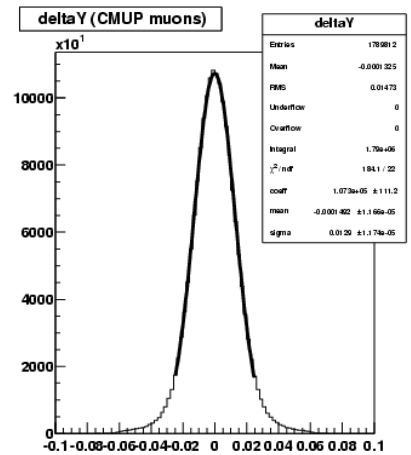
Hit Resolution

Hit, d_0 resolution from W muons before and after alignment

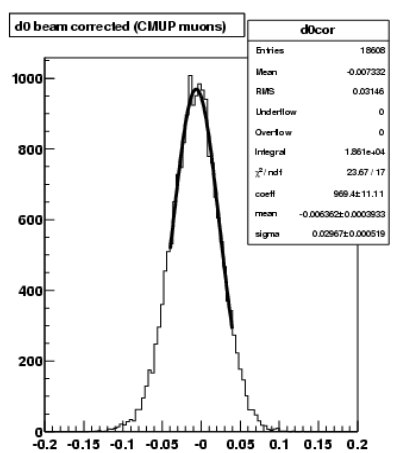
4.x hit res: 138 μm



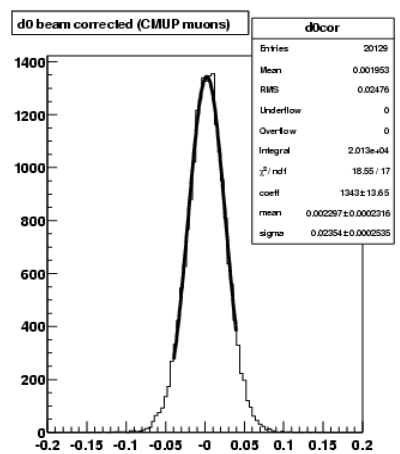
5.x hit res: 129 μm



4.x d_0 res: 297 μm



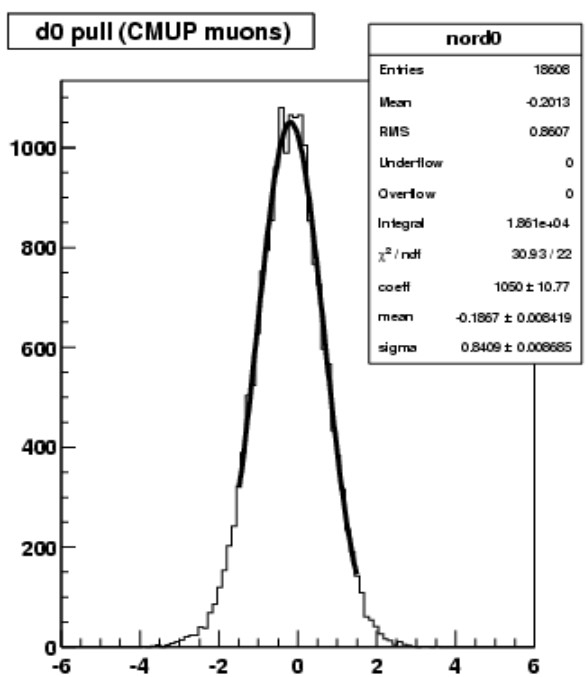
5.x d_0 res: 235 μm



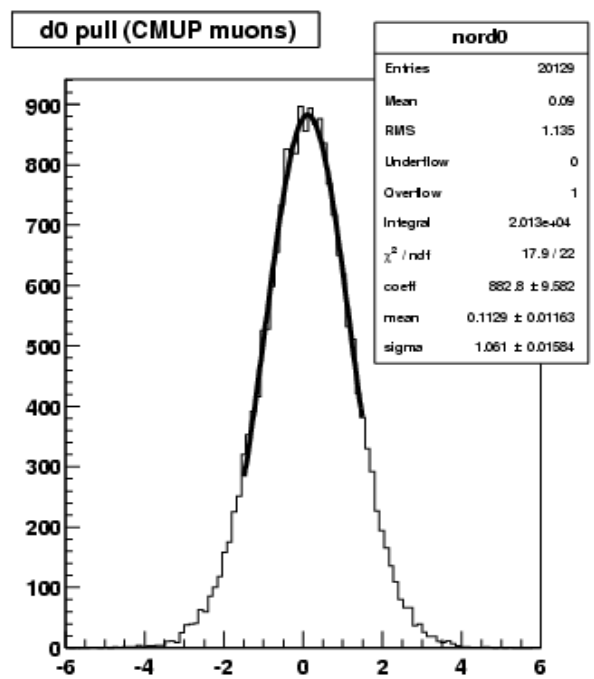
d_0 Pull

Change resolution from 235 to 140 microns
Fixes track parameter errors
Plot $d_0/\Delta d_0$

4.x d_0 pull: 0.84



5.x d_0 pull: 1.06



Yimei

defTrack Definition

Require a given # of superlayers instead of hits

- $\geq$2 axial, $\geq$2 stereo superlayers with $\geq$5 hits
- 4.8.x: $\geq$20 axial hits, $\geq$16 hits

Loosen requirements to improve efficiency for low-$\mathrm{p_T}$ or long-lived tracks
Loosen requirements for tracks that do not go through full COT

- $\geq$2 axial, $\geq$1 stereo superlayers with $\geq$5 hits

Apply χ^2 cut for tracks without silicon

- $\chi^2/\#\ hits$ <10

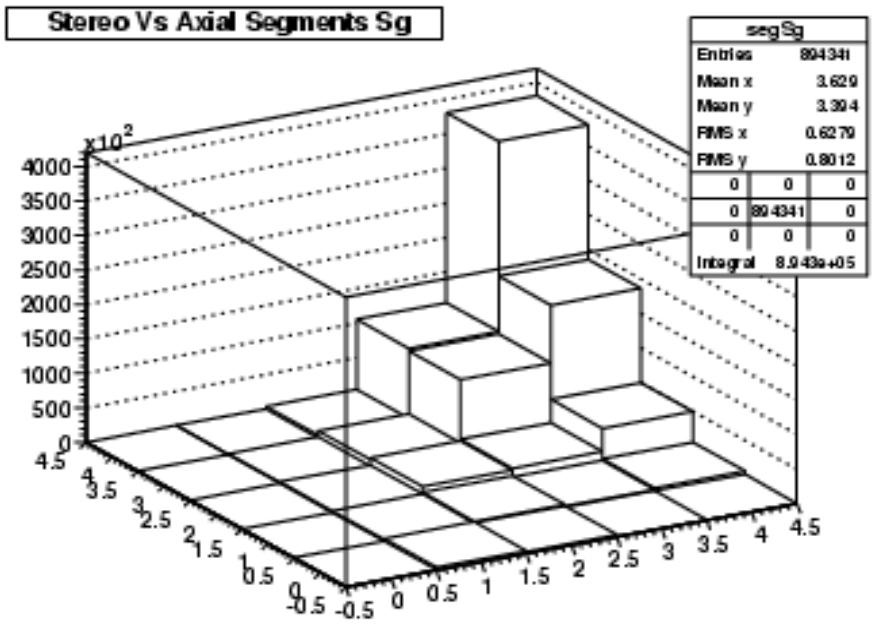
Reduces inefficiencies from signal tracks:

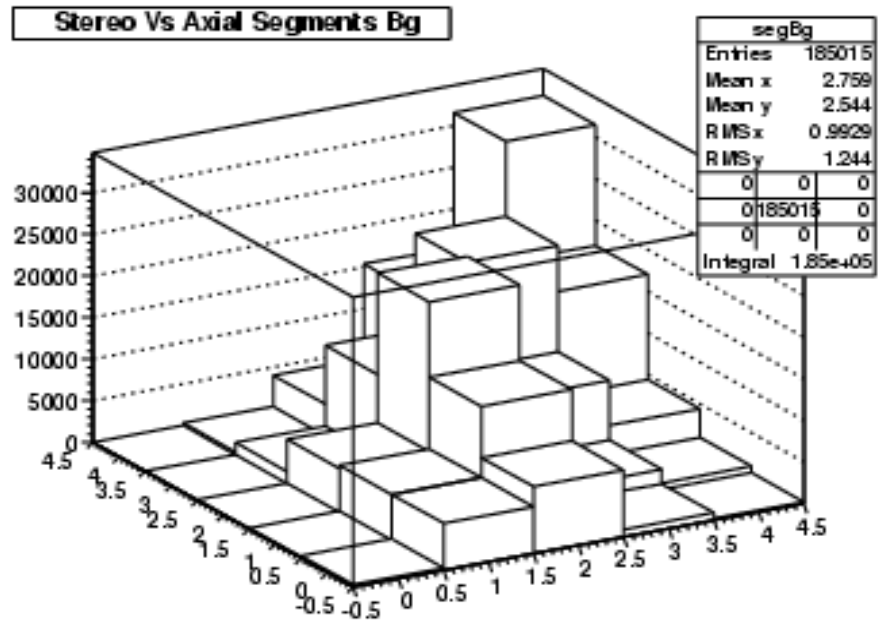
- Central K_s: inefficiency reduced from 1.2% to 0.4%
- Forward K_s: inefficiency reduced from 6.1% to 1.0%

Yimei

Number of Axial and Stereo Superlayers

Study number of axial/stereo superlayers on signal, background tracks
Use signed impact parameter: $\pm 3\sigma$ signal, -5σ background

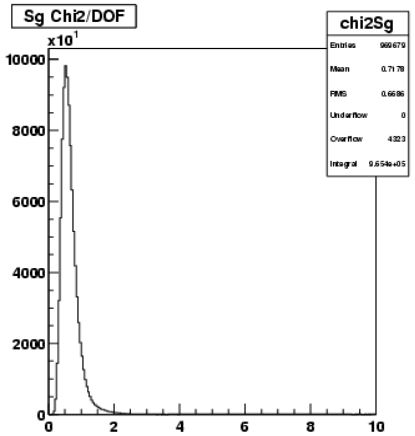




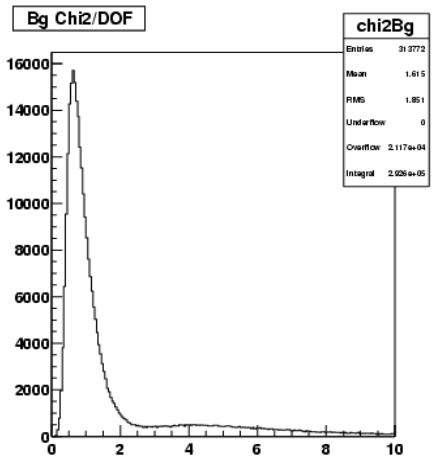
Track χ^2

Study track χ^2 for signal and background tracks

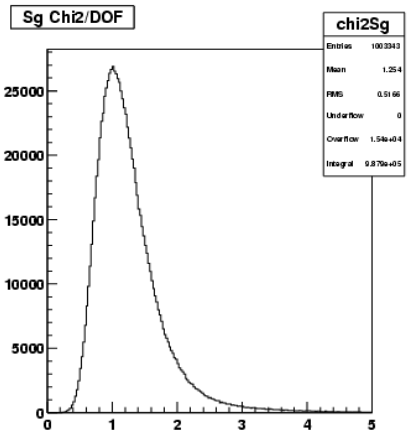
Signal, hit res 235 μm



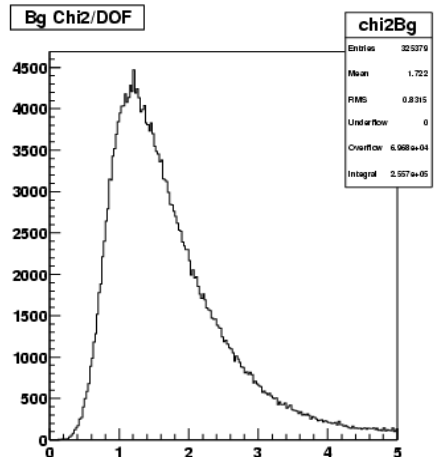
Background, hit res 235 μm



Signal, hit res 170 μm



Background, hit res 170 μm



dE/dx

Standard method of calculating dE/dx now run in production, stored in CdfTrack

Eiko, Stefano

t_0

Associate a t_0 with each z vertex

- Take best tracks ($\geq$3/3 SL's $\geq$6 hits) associated with each z vertex
- Find track t_0 using residuals in each superlayer
- Calculate vertex t_0, put in `ZVertexColl`

Can use t_0 offline to constrain the fit
Needs testing, a starting point for vertex t_0 constraint in production

Tom

Simulation

Tune Garfield resolution to 140 microns for $W \rightarrow \mu\nu$ simulation

Inside-Out Algorithm

New algorithm to improve forward tracking (*CDF Note 6707*)

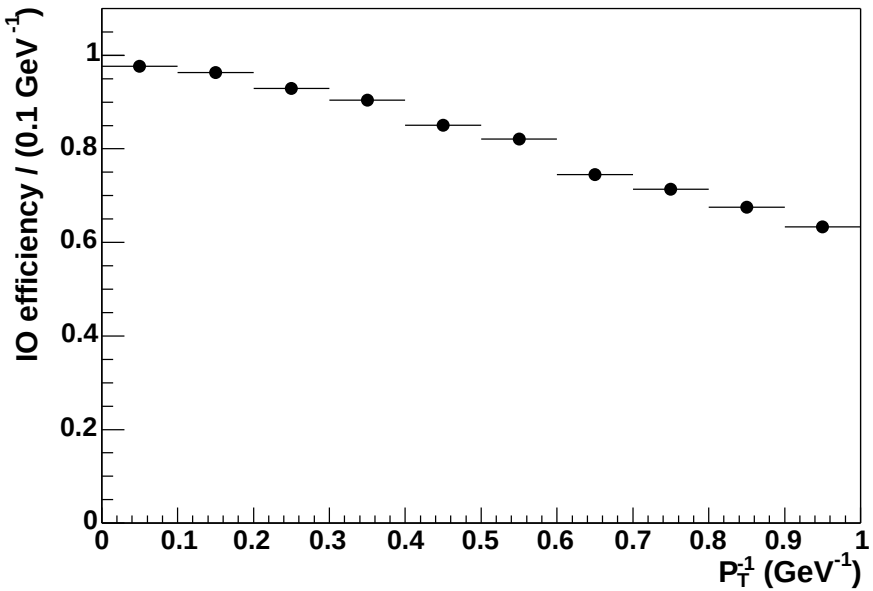
- Use silicon standalone tracks as seeds to search for hits in the COT
- Search with all tracks passing through at least 2 COT superlayers
  - COT standalone requires a track to pass through at least 4 COT superlayers
- Forward-fit silicon track to COT inner cylinder
- Same hit-search road as COT cosmic search algorithm
- Only require 6 axial, 2 stereo hits (COT standalone: 12/2)
- Fit track with silicon z_0, d_0 as constraints
- If fit succeeds, refit silicon hits with COT track as seed

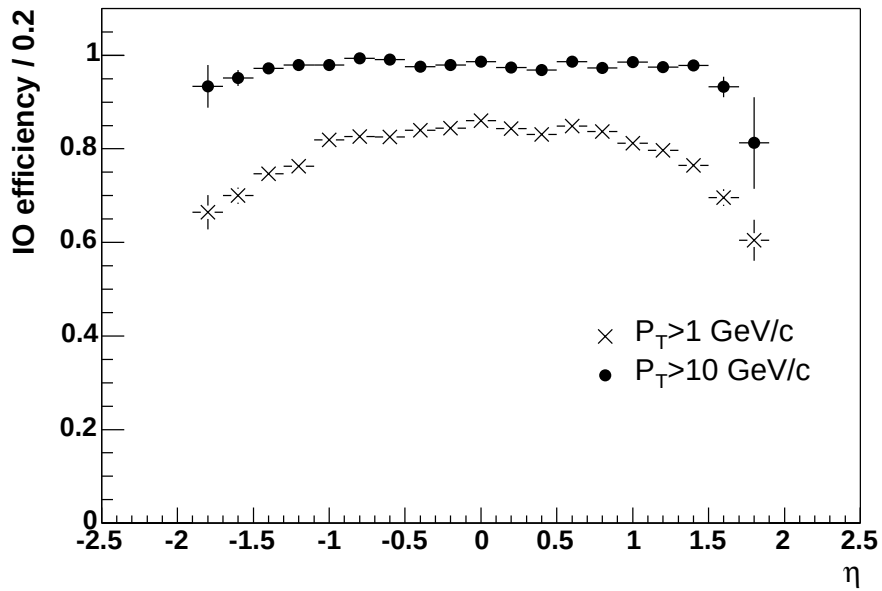
Use IO tracking to validate central silicon standalone tracks

- Eliminate SiSA tracks that pass through entire COT and do not make an IO track
- Remove IO track if its and another track's hits are at least 15% shared

Inside-Out Efficiency and Resolution

Intrinsic IO efficiency maximal for high-p_T tracks (>95% for p_T >5 GeV)





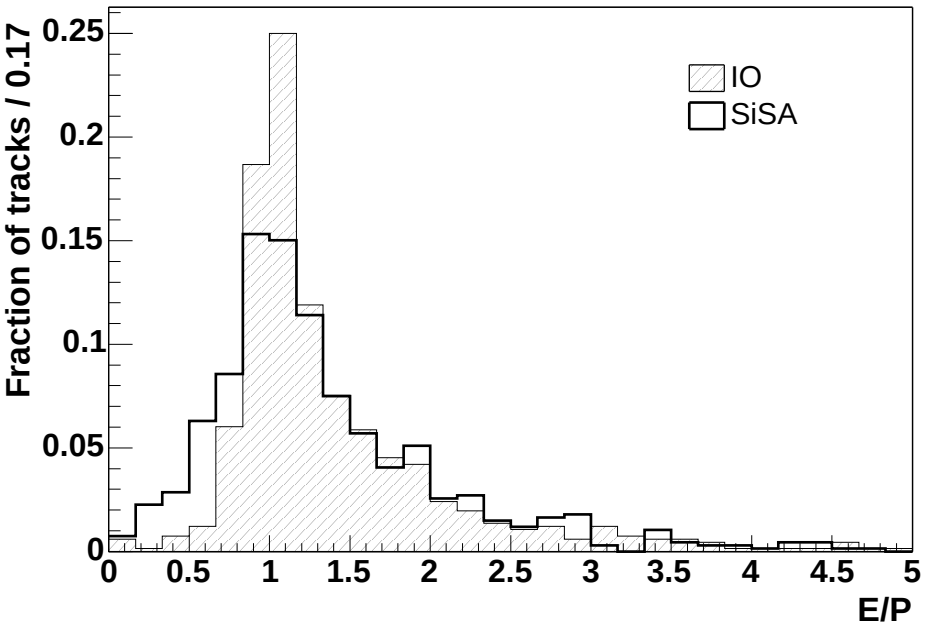
Improvement in Monte Carlo resolutions:

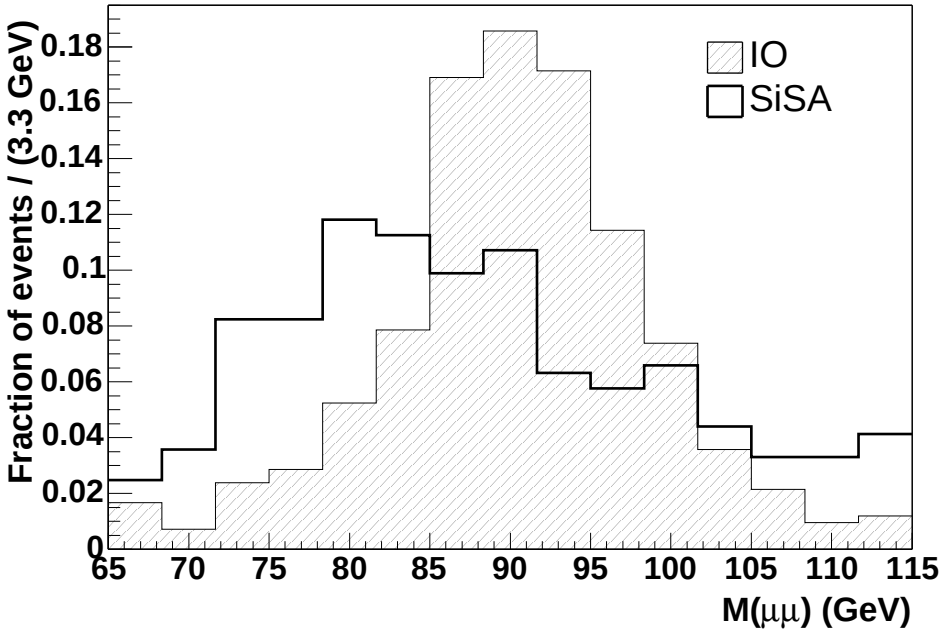
Method	Curv. RMS	ϕ_0 RMS	d_0 RMS	z_0 RMS	cotθ RMS
Si SA	$1.1\times10^{-4} cm^{-1}$	2.5×10^{-3}	61 μm	920 μm	0.015
IO	$4.6\times10^{-5} cm^{-1}$	2.1×10^{-3}	53 μm	650 μm	0.011

IO Data Resolution

E/p from plug electrons in Z events
Z mass from forward muons

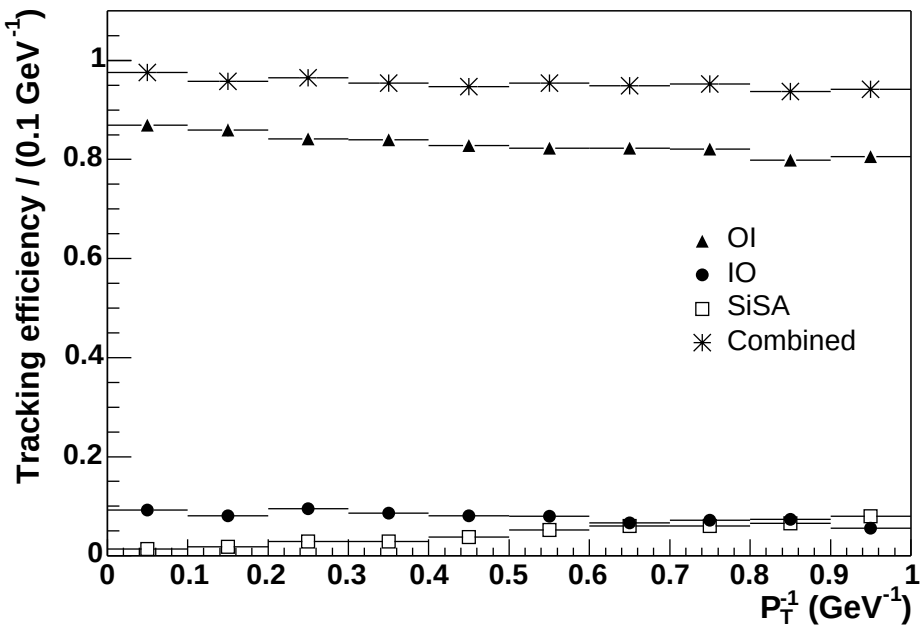
- RMS decreases from 12.5 GeV to 9.0 GeV
- 15% increase in events in Z mass region, 57% decrease in events with m>115 GeV

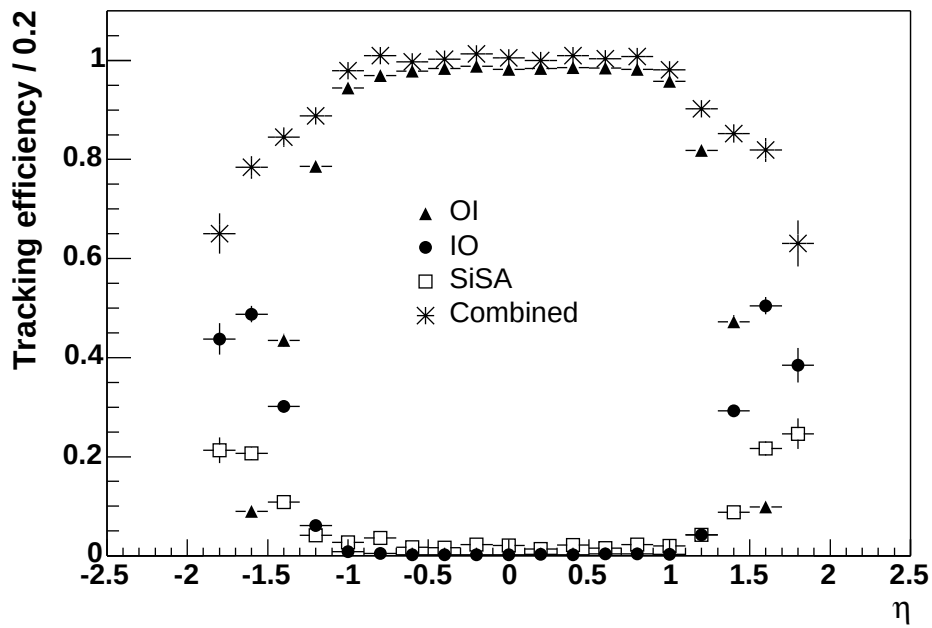




Efficiency by Algorithm Type

Algorithm efficiency for the final track collection (tracks pass through $\geq$2 COT SL's):

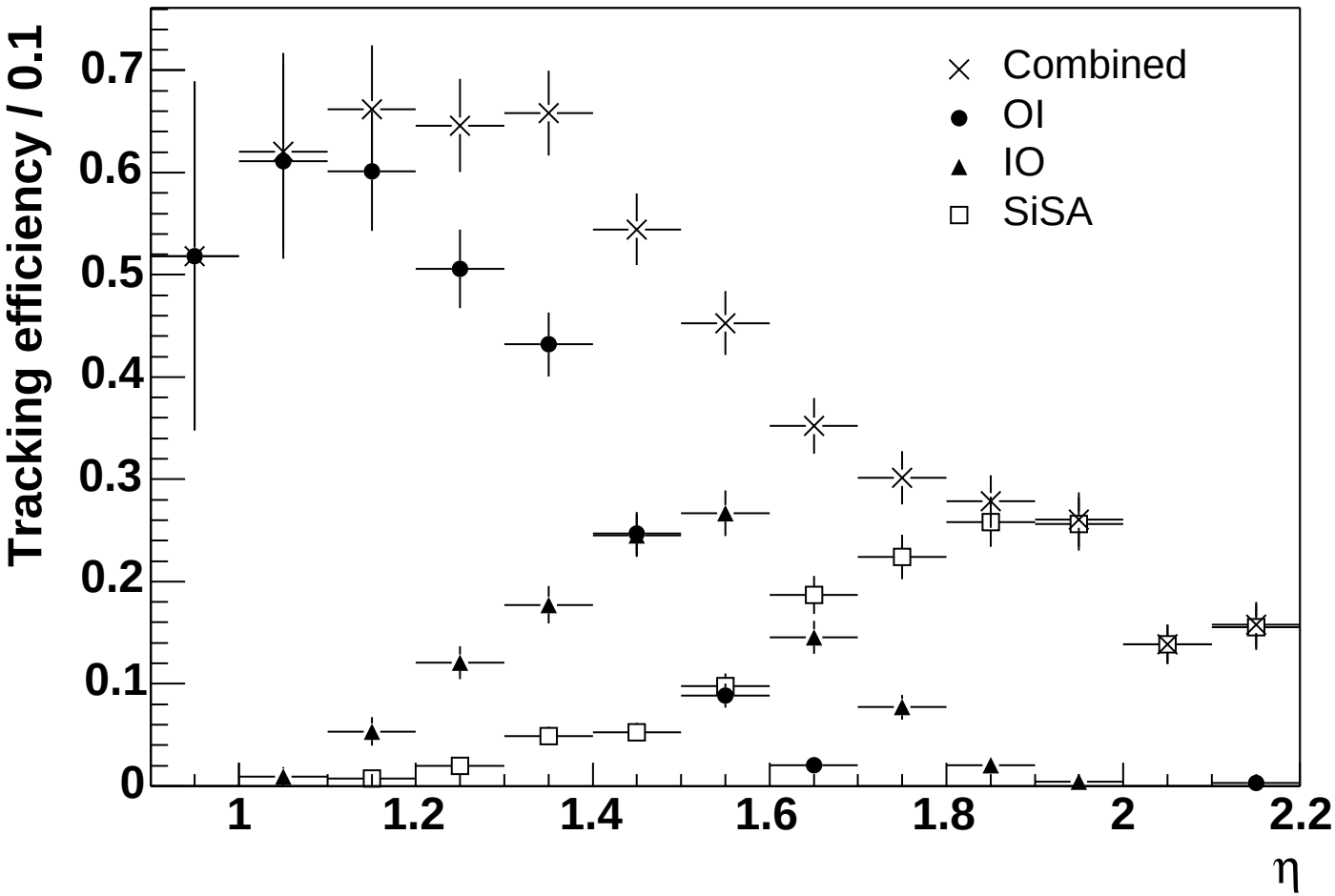




Yimei: Code validation and implementation details
Rick S.: Early structural code
Karlsruhe (Kurt, Stephanie, Claudia): Outward silicon fit; SiSA tracks
Ashutosh, Heather: COT search road
Avi: Idea for incorporating into defTracks

Forward Track Data Efficiency

Algorithm efficiency for plug electrons in Z events:



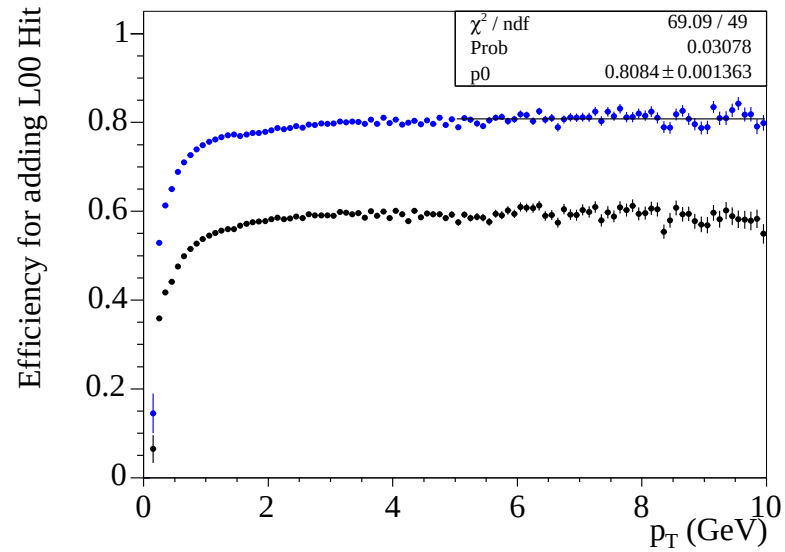
L00

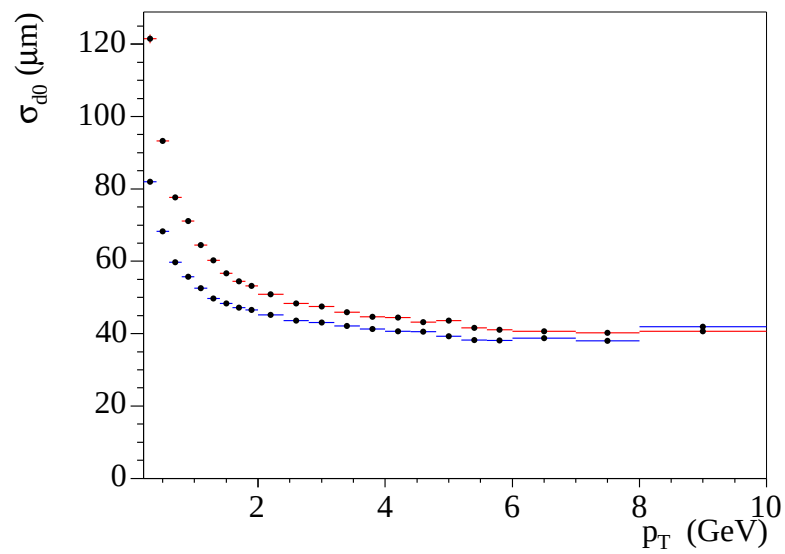
Clustering quality cuts defined
Alignment to $10\mu m$ level
Efficiency of tracks pointed into active area

- Max efficiency 80.8%
- High-quality clusters: 59.2%

d_0 at low momentum improves dramatically

Tim: L00 construction
Chris Hill, David Stuart, Auke-Pieter Colijn: Pedestal fit
Aaron, Jason: Implementation in code
Lester: Cluster cuts
Ray, Juan Pablo, Bernd: Alignment
Matt: Code for attaching hits post-production





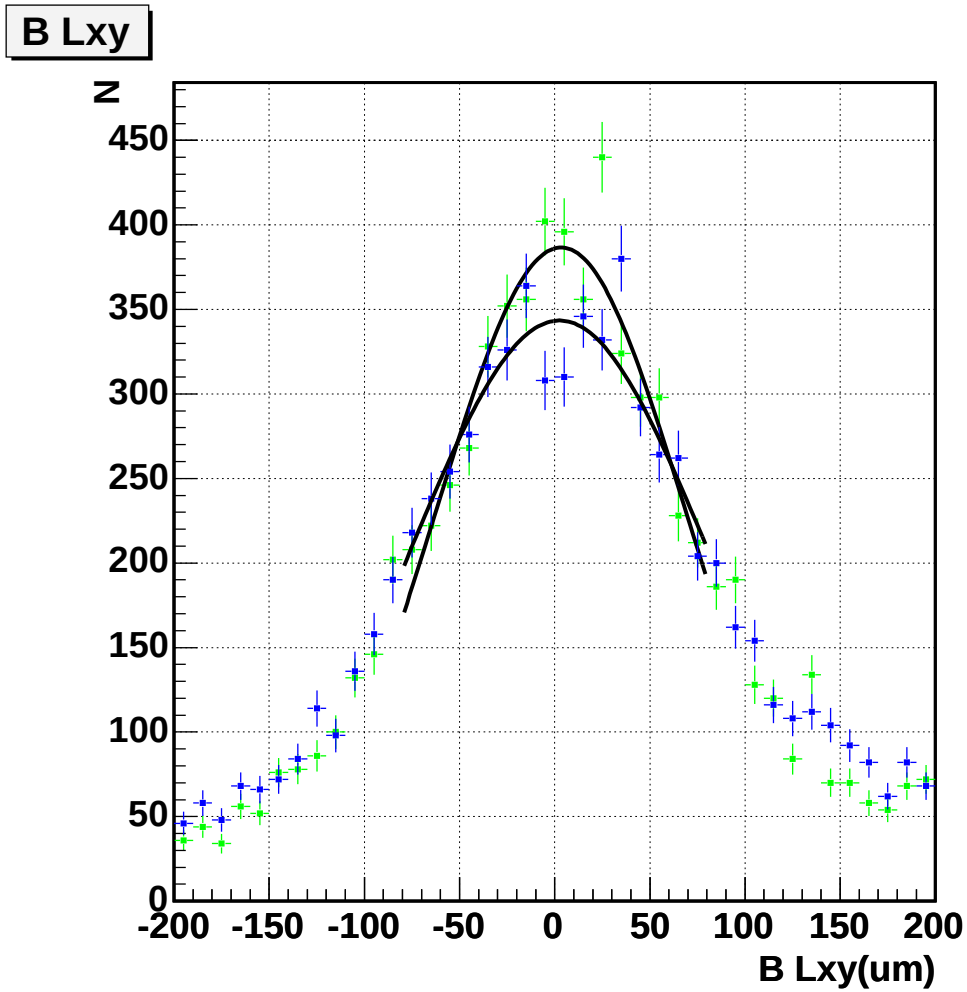
L00 in Physics: $J/\psi K$

62.4% efficiency passing cuts per track
Lxy Resolution and tails

- Improvement in Lxy resolution
  - Fit area $\pm 80\mu\mathrm{m}$ from the center of the distribution
  - With L00: $64 \pm 3\mu\mathrm{m}$
  - Without L00: $78 \pm 4\mu\mathrm{m}$
- Tails
  - With L00: 1702 beyond -3σ
  - Without L00: 1842 beyond -3σ

Mass resolution improvement

- Fit to Gaussian + linear: not fancy
  - With L00: $14.3 \pm 1.0\mathrm{MeV}$
  - Without L00: $15.2 \pm 1.0\mathrm{MeV}$



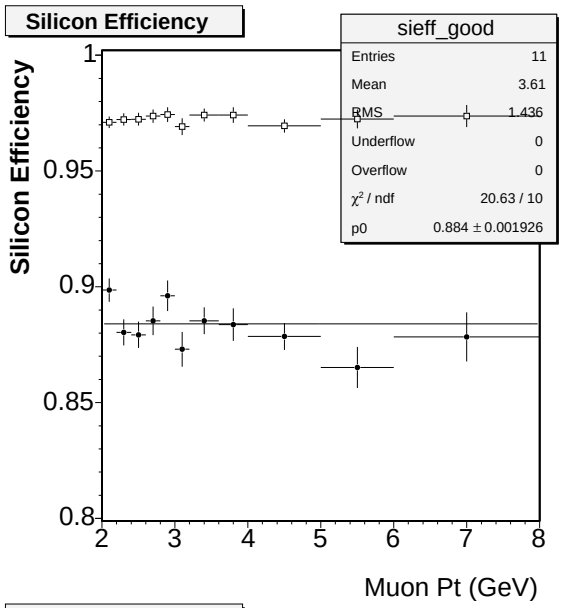
Expand Silicon Road

Road set to 1 mm until first hit is found

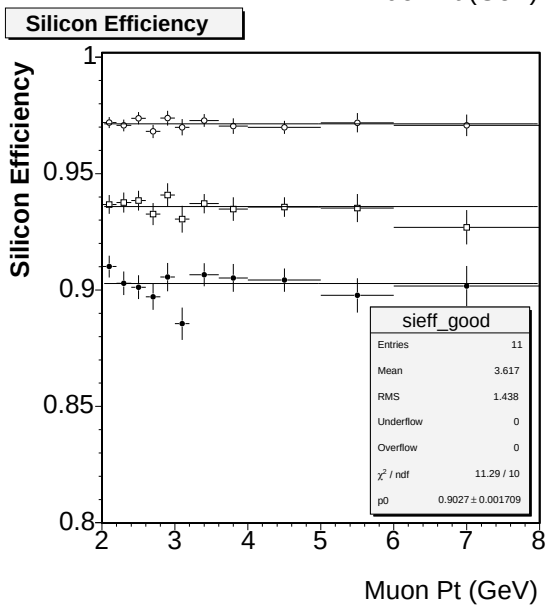
Increases efficiency of attaching silicon

- J/ψ muons (plots)
  - Efficiency improves from $88.4\% \rightarrow 90.3\%$
  - Include 3-hit tracks (5 expected): additional 3% gain
  - Fake rate the same: 1.18%
- Jets
  - Efficiency at high momentum up: $73.3\% \rightarrow 83.0\%$
  - Fake rate down: 1.2%

Matt



4.8.4

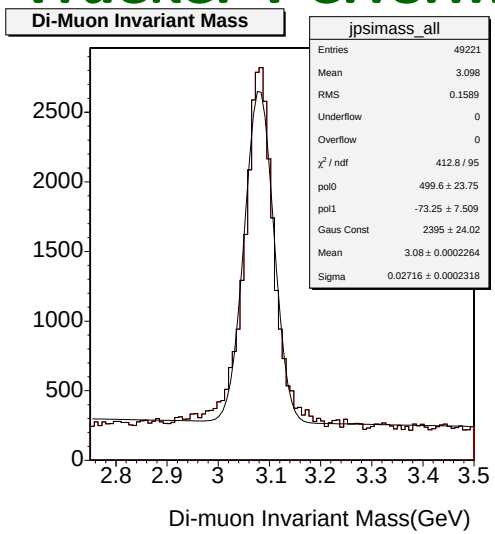


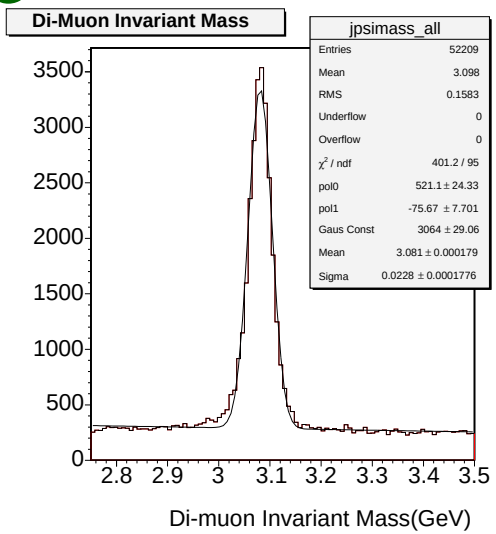
5.1.0

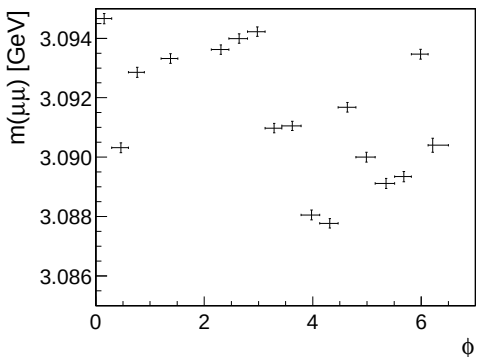
Combined Tracker Performance

COT/Silicon J/ψ Mass resolutions

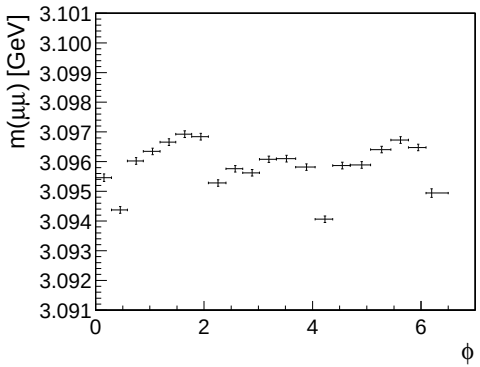
- COT width: $27\text{MeV} \rightarrow 23\text{MeV}$
- OI width: $15\text{MeV} \rightarrow 14\text{MeV}$
- Phi effects reduced





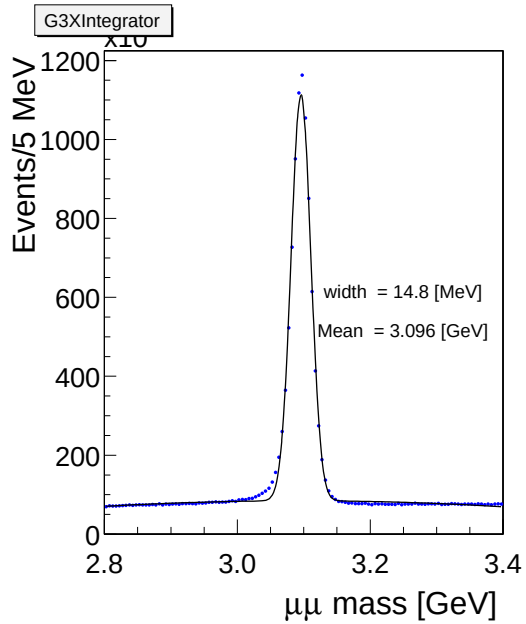


4.8.4

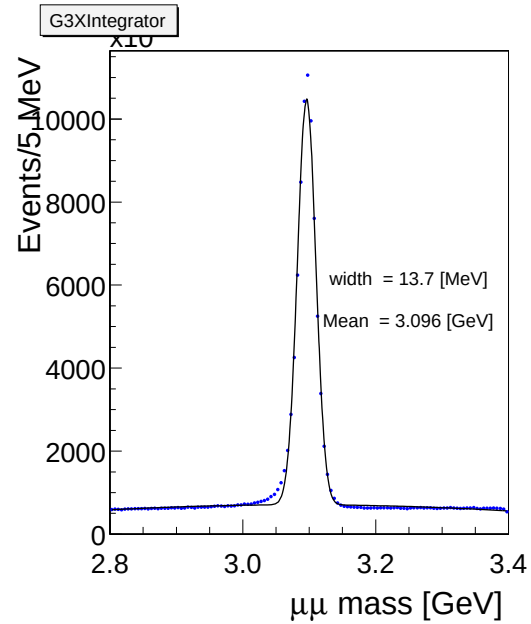


5.1.0

4.8.4



5.1.0

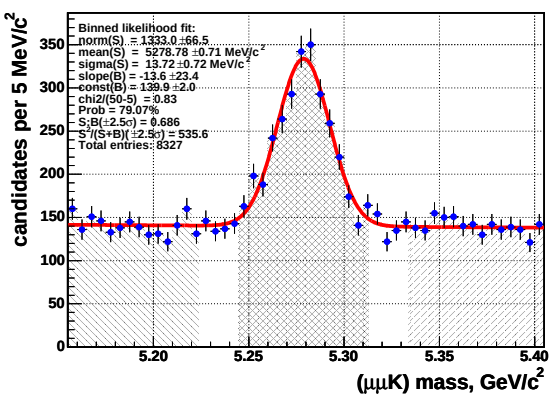


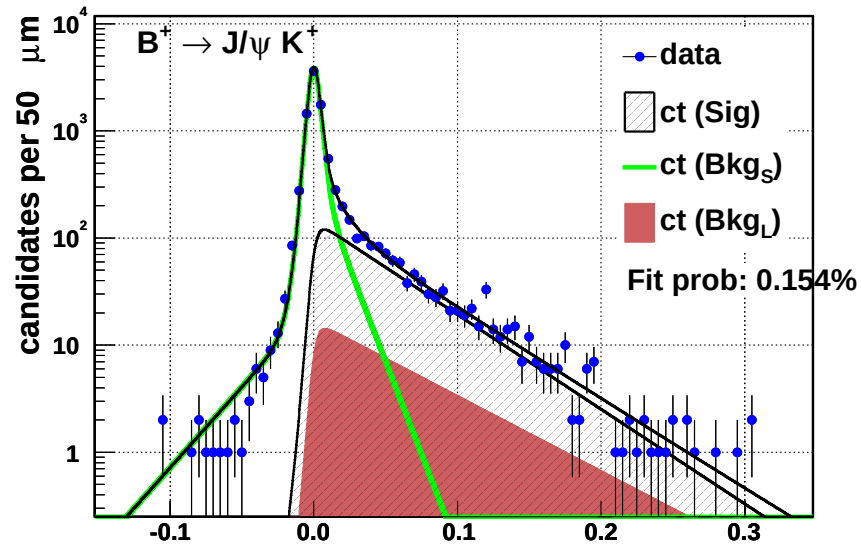
Andreas

Physics Validation: $\mathrm{B} \rightarrow \mathrm{J}/\psi\mathrm{K}$

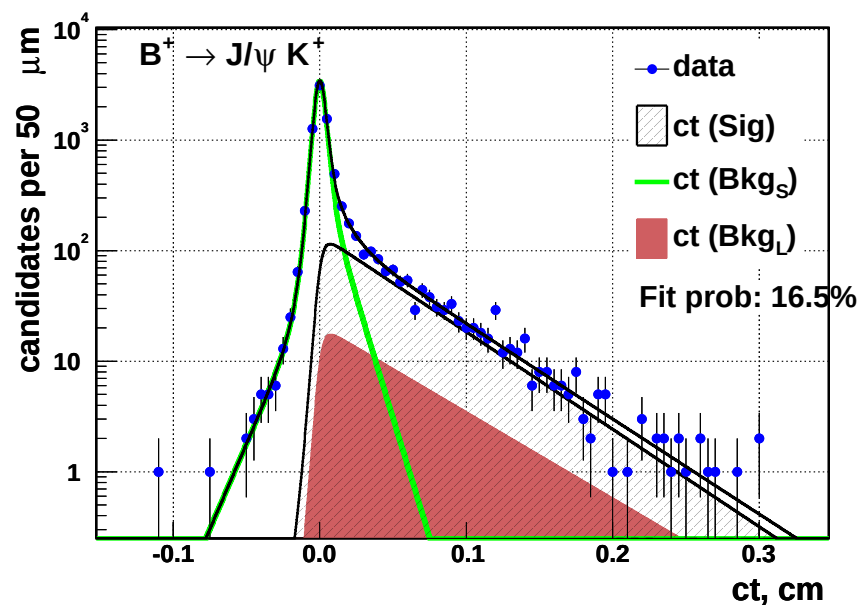
Validation Strategy

- 4.8.4 vs. 5.1.0
- Perform $\mathrm{B} \rightarrow \mathrm{J}/\psi\mathrm{K}$ lifetime analysis
- Compare all quantities from fit
- Comparisons of interest
  - Mass width: $16\mathrm{MeV} \rightarrow 14\mathrm{MeV}$
  - ct fit probability $0.15\% \rightarrow 16.5\%$
  - mass fit probability $0.3\% \rightarrow 77.3\%$
  - Notice tail of the $c\tau$ distribution
  - S/N slightly improved





4.8.4



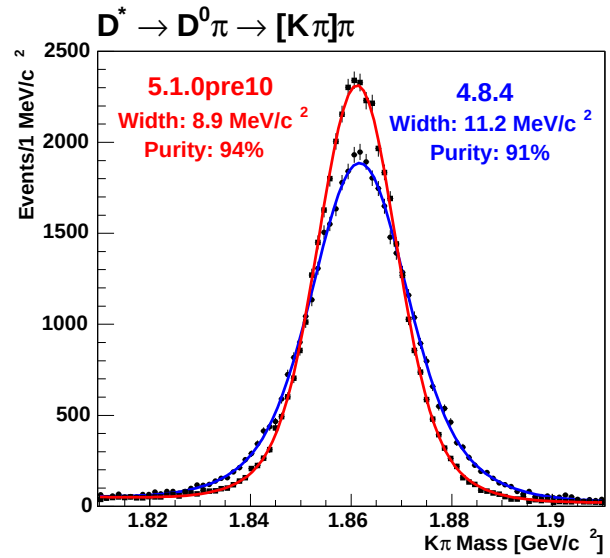
5.1.0

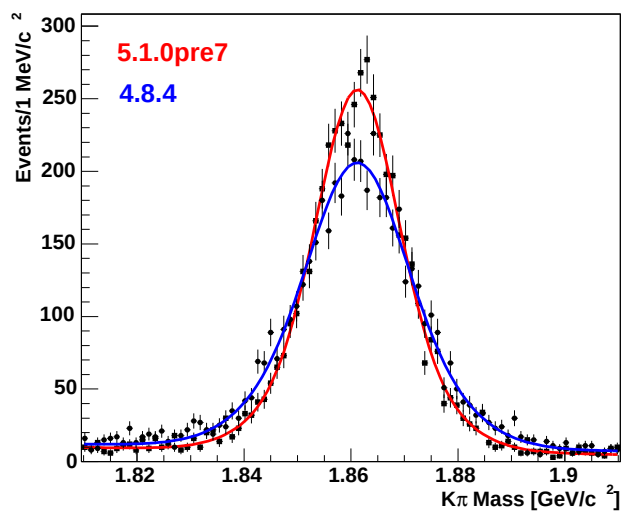
Physics Validation: $D^* \to D^0\pi$

Validation Strategy

- 4.8.4 vs. 5.1.0
- Pre-selected D^*
  - Soft pion: validation of low-momentum tracking
  - Purity and width improve
  - A few new candidates
- Unbiased D^* sample
  - Same cuts: Yield 3% higher
  - New defTrack cuts: Yield 9% higher

Stefano





Beyond 5.x

COT Plans

- Alignment as a function of z *(Ashutosh, Aseet)*
- Vertex t_0 as a track constraint?
- Improved drift model near and far from wires *(Kevin B.)*
- Simulation hit efficiencies *(Simon)*

Inside-Out Plans

- Define search road using silicon track parameters

Silicon Plans

- Increase silicon standalone efficiency, validate *(Stephanie, Thorsten, Florencia)*
- Phoenix tracking for muons *(Dan Cyr, Tim)*
- Understand stereo resolution
- Tune L00 cuts
- Silicon dE/dx *(Andy, Ingyin)*
- Parametric model for L00 *(Michael Gold, Sebastian)*