UNIVERSITY OF CALIFORNIA SANTA CRUZ

International Linear Collider

Simulation Results from the Santa Cruz Linear Collider Group

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Tracking Performance of an All-Silicon Tracker

Thanks to Michael Young (UCSC Master's student), Eric Wallace, Lori Stevens, and Tyler Rice (UCSC undergraduates)

Goals:

- Verify tracking efficiency for all-silicon tracking
- Verify track parameter resolution

TRACKING CODE

Available track reconstruction/fitting is VXDBasedReco, due to **Nick Sinev** (Oregon).

- Start with segment from VXD
- Attach tracker hits (at least one hit needed to reduce bckgd)

Can be run with no hit smearing, gaussian smearing, or realistic CCD hit smearing (realistic μstrip smearing still under development).

NOTE: VXDBasedReco not yet available in new (LCIO) framework; these results are >1 year old!

Also: we use **Wolfgang Walkowiak's** TrackEfficiencyDriver for the core of the tracking efficiency calculation.

EVENT/TRACK SELECTION

Choose qqbar events at E_{cm}= 500 GeV (dense jet cores)

Choose events/tracks that should be easily reconstructed (tracks curl up below $p_{\perp}$= 1 GeV):

Event Selection

- $|\cos\theta_{thrust}| < 0.5$
- Thrust Mag > 0.94

Track Selection

- $|\cos\theta_{track}| < 0.5$
- $p_{\perp} > 5$ GeV/c

SOME PRELIMINARIES

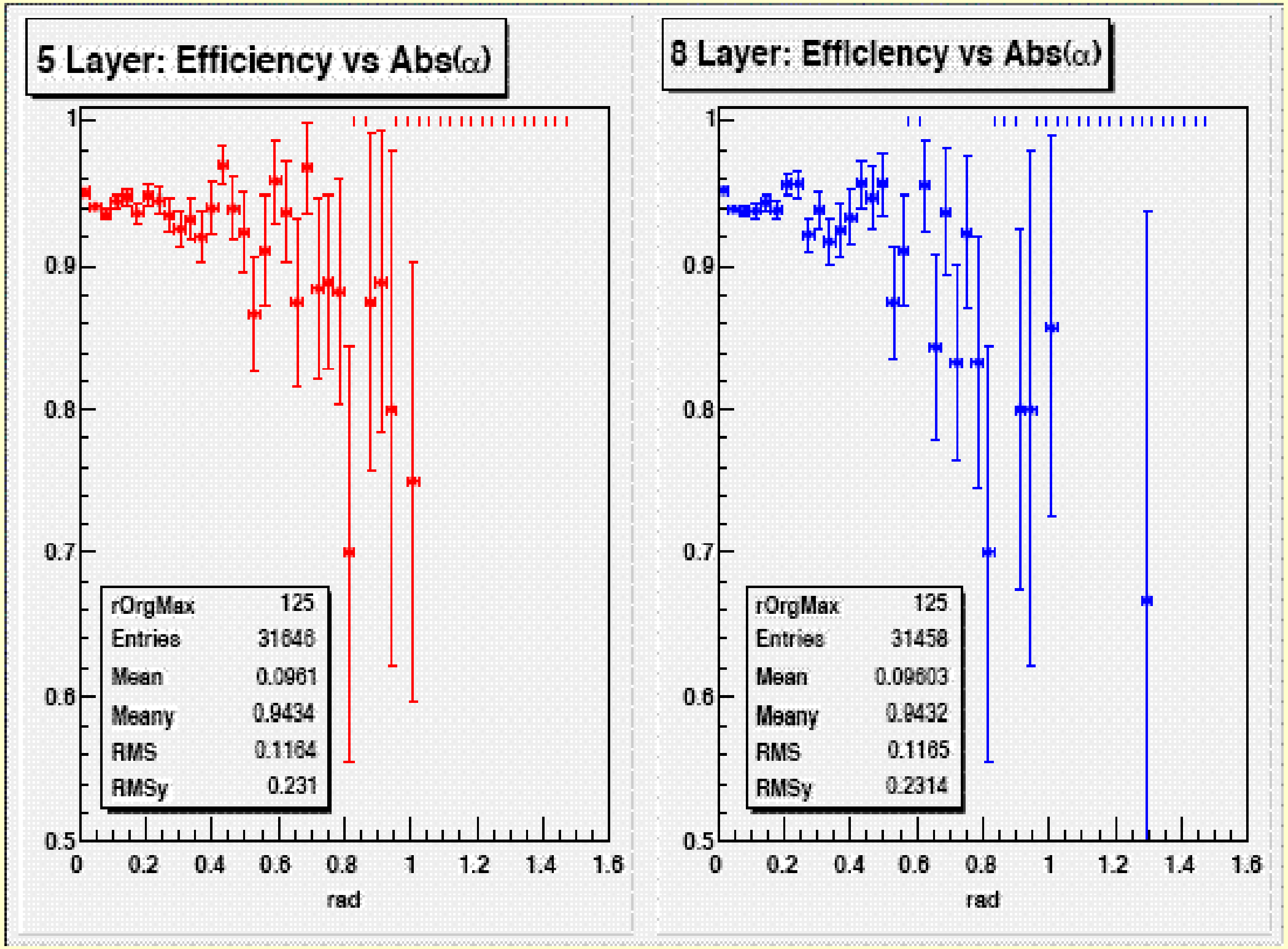
1. Gaussian variable related to momentum resolution is *curvature* ω, inversely related to $p_\perp$ and radius of curvature R according to

$$\omega = 1/R = 0.003 * B(T) * (1/p_\perp)$$

2. Define α as angle between track and jet core, where jet core angle is taken to be the thrust axis.

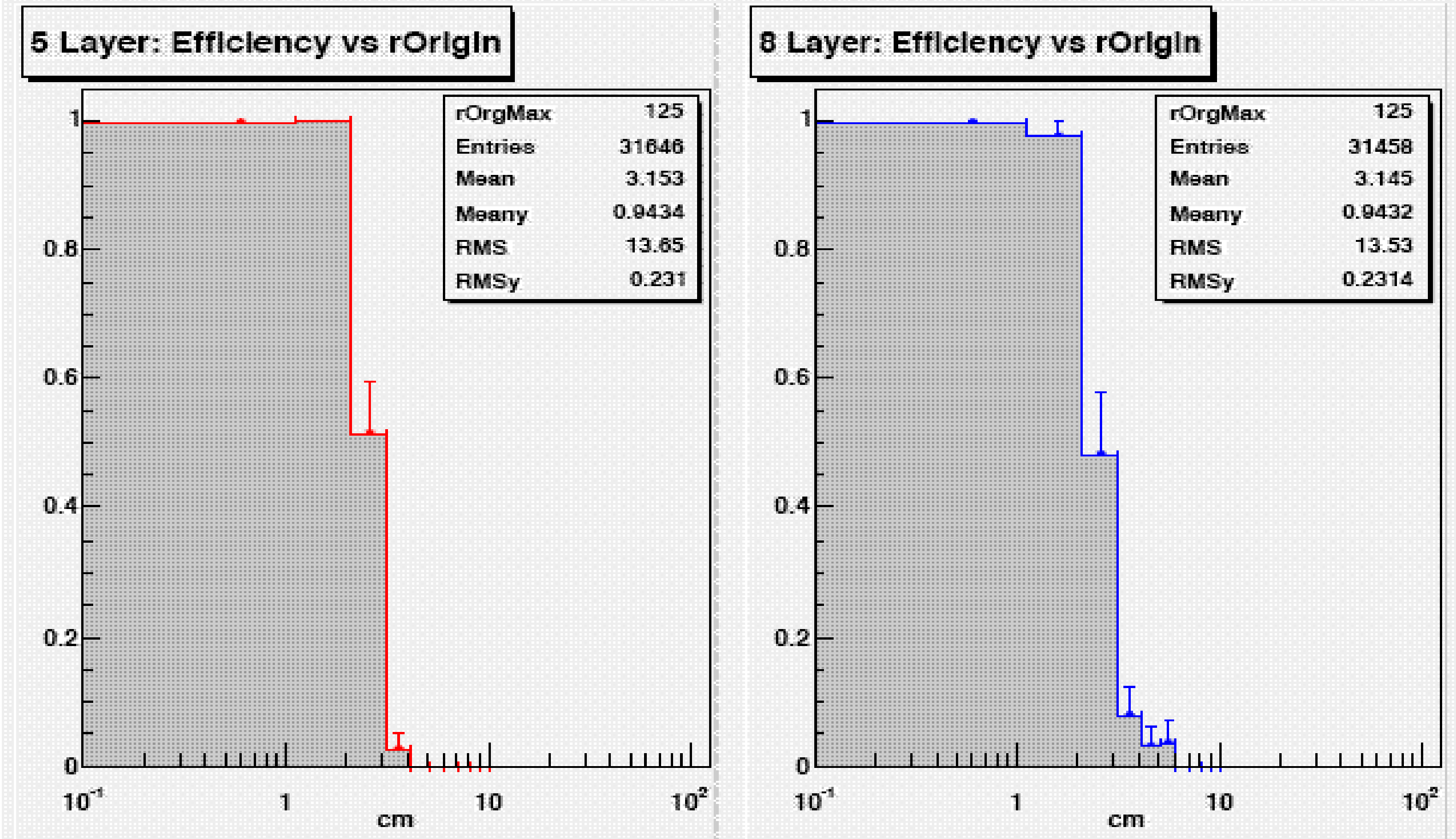
3. All fitting studies done without beam constraint

EFFICIENCIES FOR QQBAR EVENTS



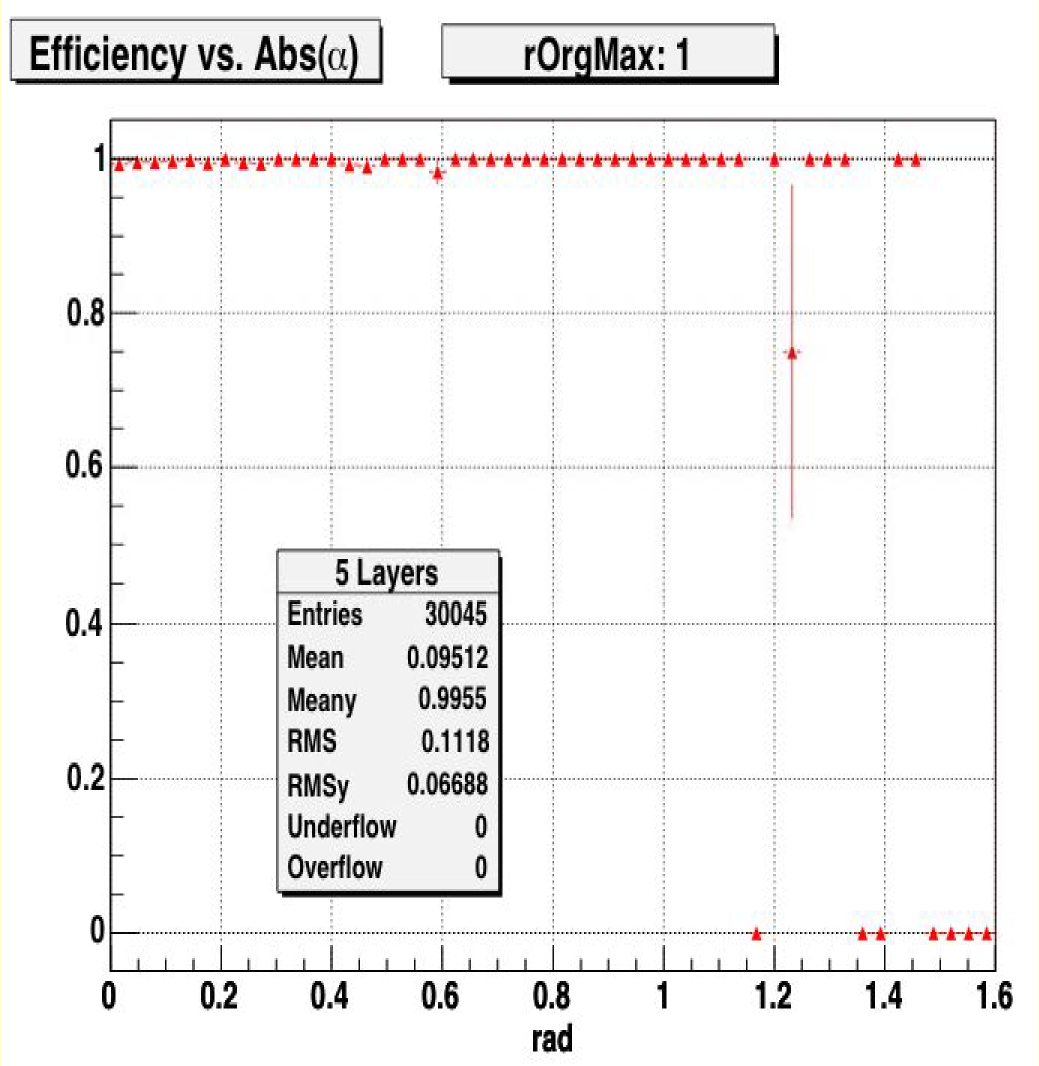
Doesn't look that spectacular; what might be going on here?

Of course! The requirement of a VXD stub means that you miss anything that originates beyond r ~ 3cm. This is about 5% of all tracks.

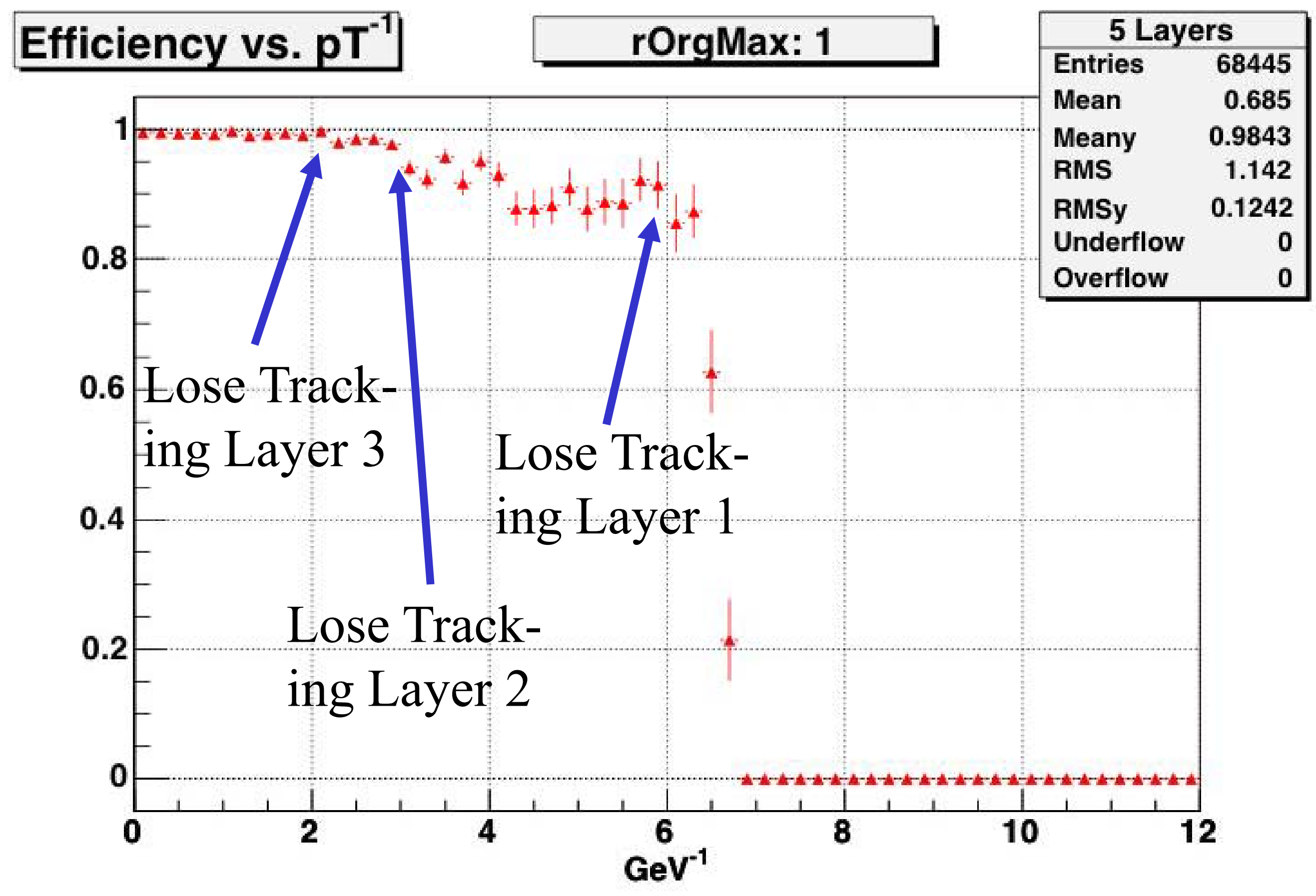


With VXDBasedReco, we won't see a difference between 5 and 8 layer tracking.

So – what is the efficiency for tracks that originate within the beampipe?



Efficiency Versus Transverse Momentum

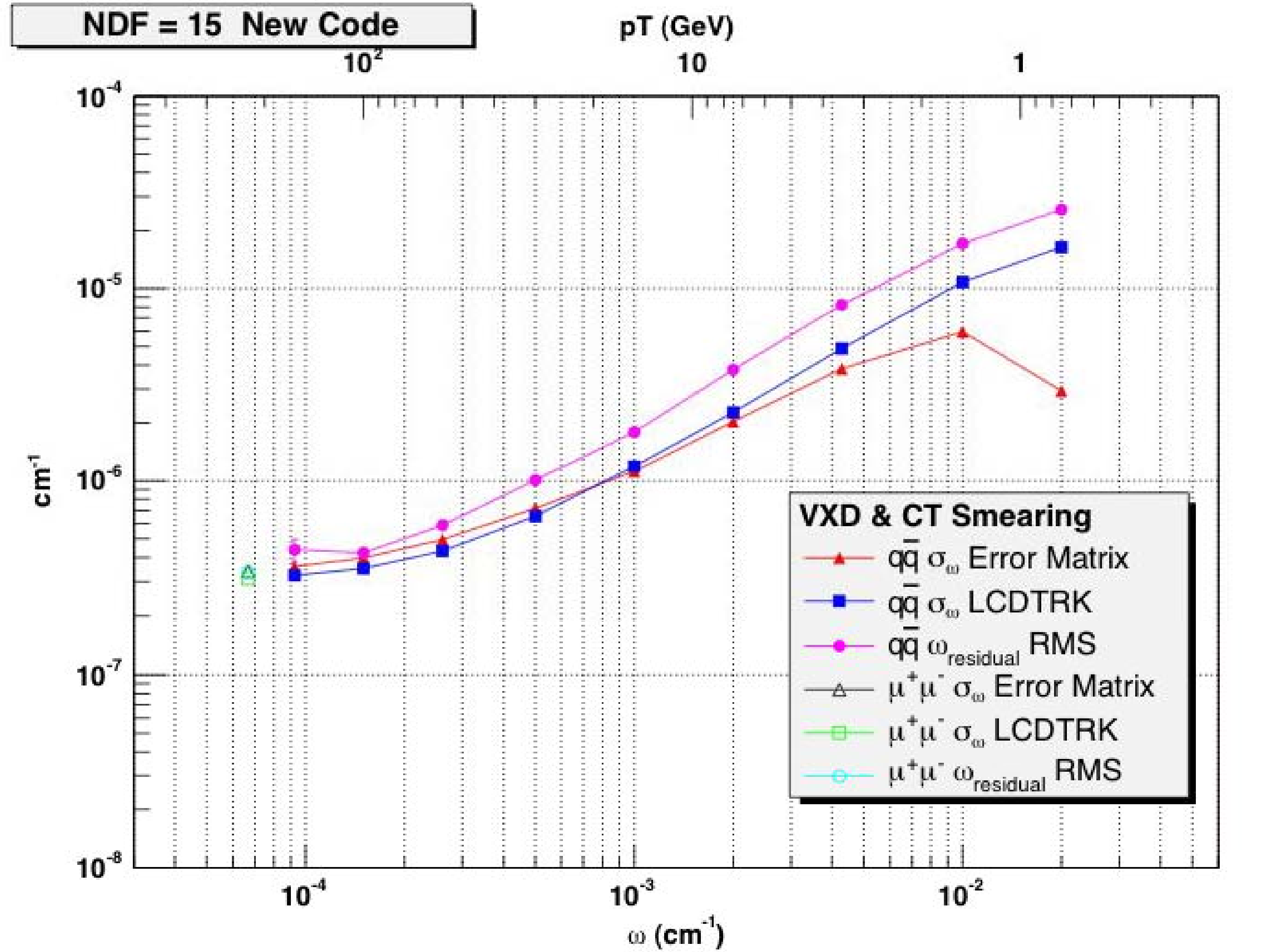


TRACK PARAMETER PERFORMANCE

1. Compare width of Gaussian fit to residuals with two different estimates:
   - Error from square root of appropriate diagonal error matrix element
   - Error from Billior calculation (LCDTRK program)
2. Only tracks with all DOF (5 VTX and 5 CT layers) are considered.
3. Only gaussian smearing is used, since this is what is assumed for the two estimators.

Qqbar sample extends out to ~100 GeV; use $\mu^+\mu^-$ sample to get higher energy (200-250 GeV) bin.

CURVATURE ERROR vs. CURVATURE



Code With Modified Fitter

RESULTS FOR μμ (LOWEST ω BIN)

Residuals (Gaussian smear): $\delta\omega = 3.40 \times 10^{-7}$

Error Matrix: $\delta\omega = 3.12 \times 10^{-7}$

LCDTRK: $\delta\omega = 3.26 \times 10^{-7}$

Actual momentum resolution is about 9% worse than LCDTRK expectation

Residuals (realistic CCD): $\delta\omega = 3.29 \times 10^{-7}$

Apparently, “realistic” CCD resolution is better than assumed value of 5μm

RECONSTRUCTING NON-PROMPT TRACKS

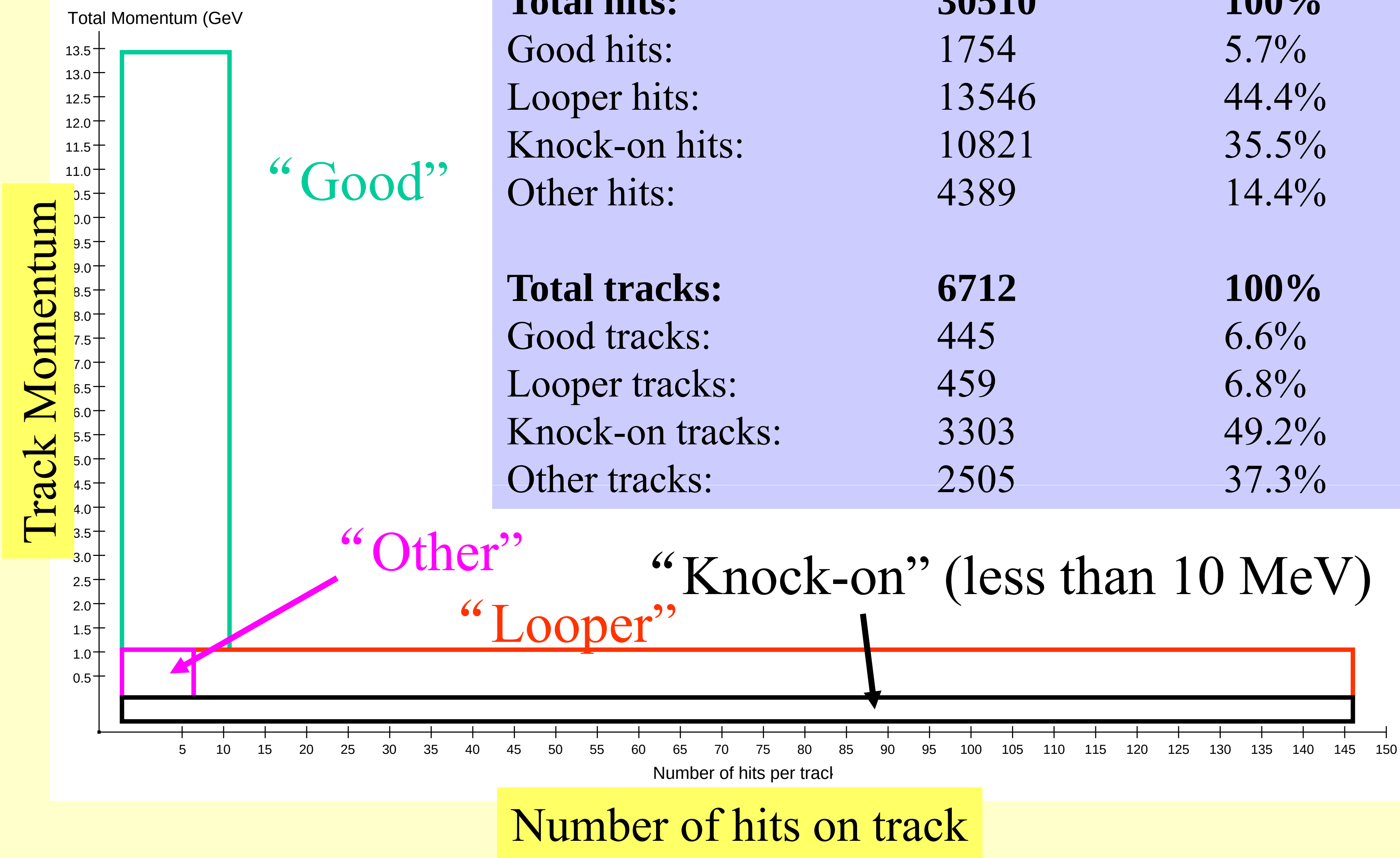
- Snowmass '05: Tim Nelson wrote axial-only algorithm to reconstruct tracks in absence of Vertex Detector
- UCSC idea: use this to "clean up" after vertex-stub based reconstruction (VXDBasedReco)
- About 5% of tracks originate beyond the VXD inner layers
- For now: study Z-pole qq events

Cheater

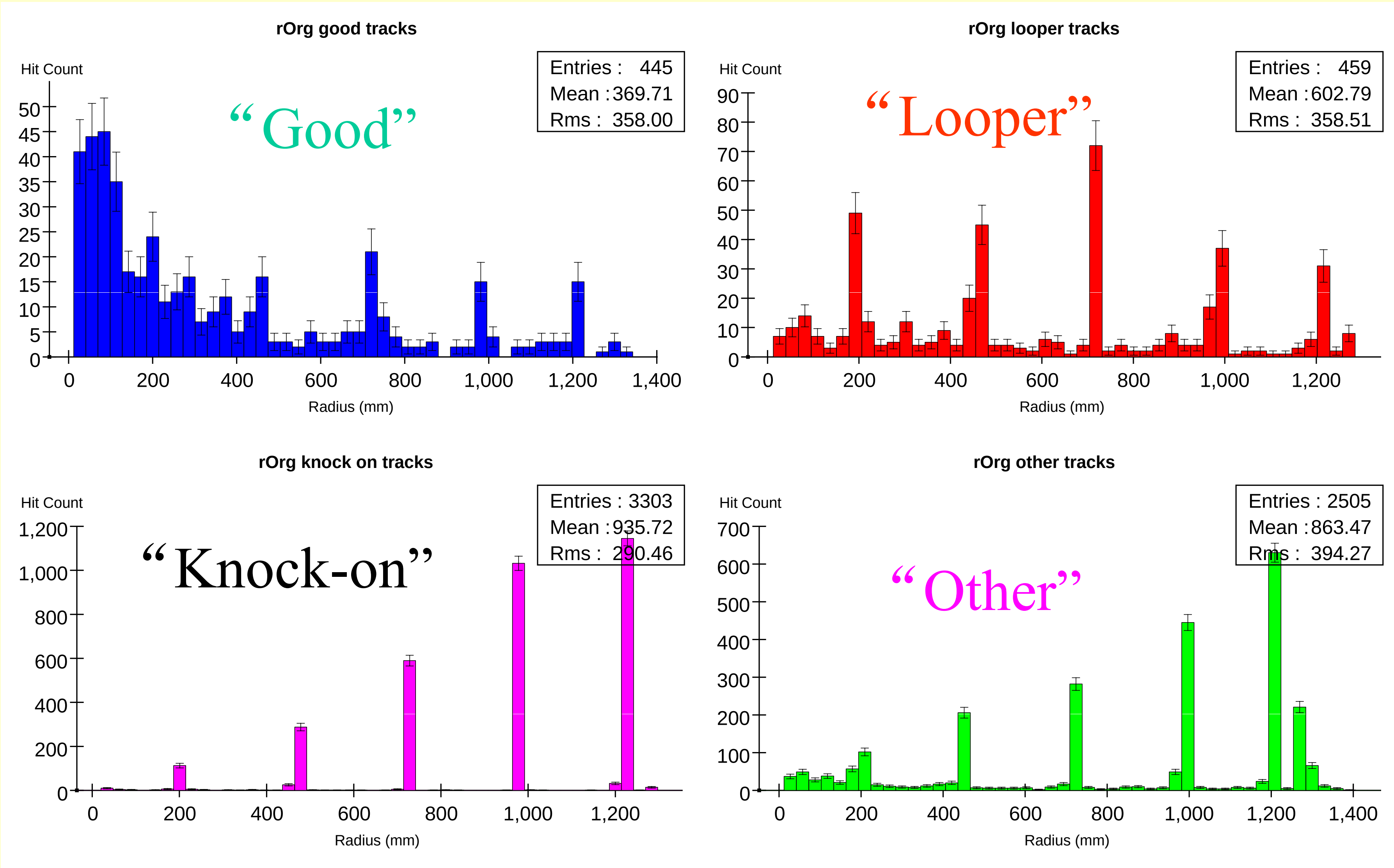
- VXDBasedReco had not yet been ported to org.lcsim framework, so…
- Wrote "cheater" to emulate perfectly efficient VXDBasedReco; assume anything that can be found by VXDBasedReco is found and the hits flagged as used
- Loops over TkrBarrHits and MCParticles, finds particles with rOrigin < 20mm and hits from those particles, removes them from collections
- rOrigin defined as sqrt(particle.getOriginX()^2 + particle.getOriginY()^2)

What's Left after "Cheating"? (258 events, no backgrounds)

Total hits:	**30510**	**100%**
Good hits:	1754	5.7%
Looper hits:	13546	44.4%
Knock-on hits:	10821	35.5%
Other hits:	4389	14.4%
Total tracks:	**6712**	**100%**
Good tracks:	445	6.6%
Looper tracks:	459	6.8%
Knock-on tracks:	3303	49.2%
Other tracks:	2505	37.3%



And where do these tracks originate?



Radius of Origin (mm) Of Tracks

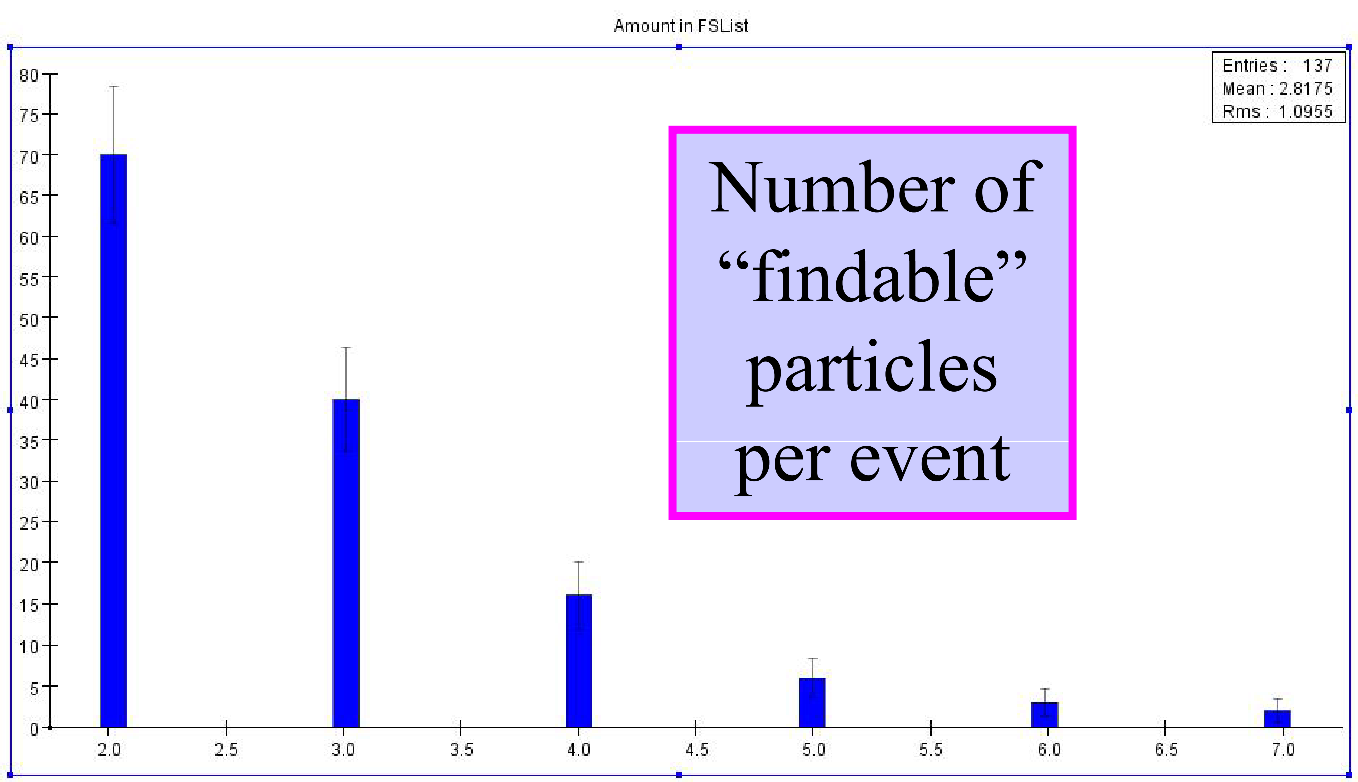
AxialBarrelTrackFinder (Tim Nelson, SLAC)

- Loops over all hits in each layer, from the outside in, and finds 3 “seed” hits, one per layer
- Performs CircleFit (alogrithm provided by Norman Graf) to seed hits
- If successful, looks for hits on the remaining layers that can be added to seed fit, refitting after each hit added.
- If at least 4 hits on track, and Chi^2 of fit reasonable, creates track object and adds to collection
- Only two (half-barrel) segments in z for now

AxialBarrelTrackFinder Performance

Define "findable" particle as

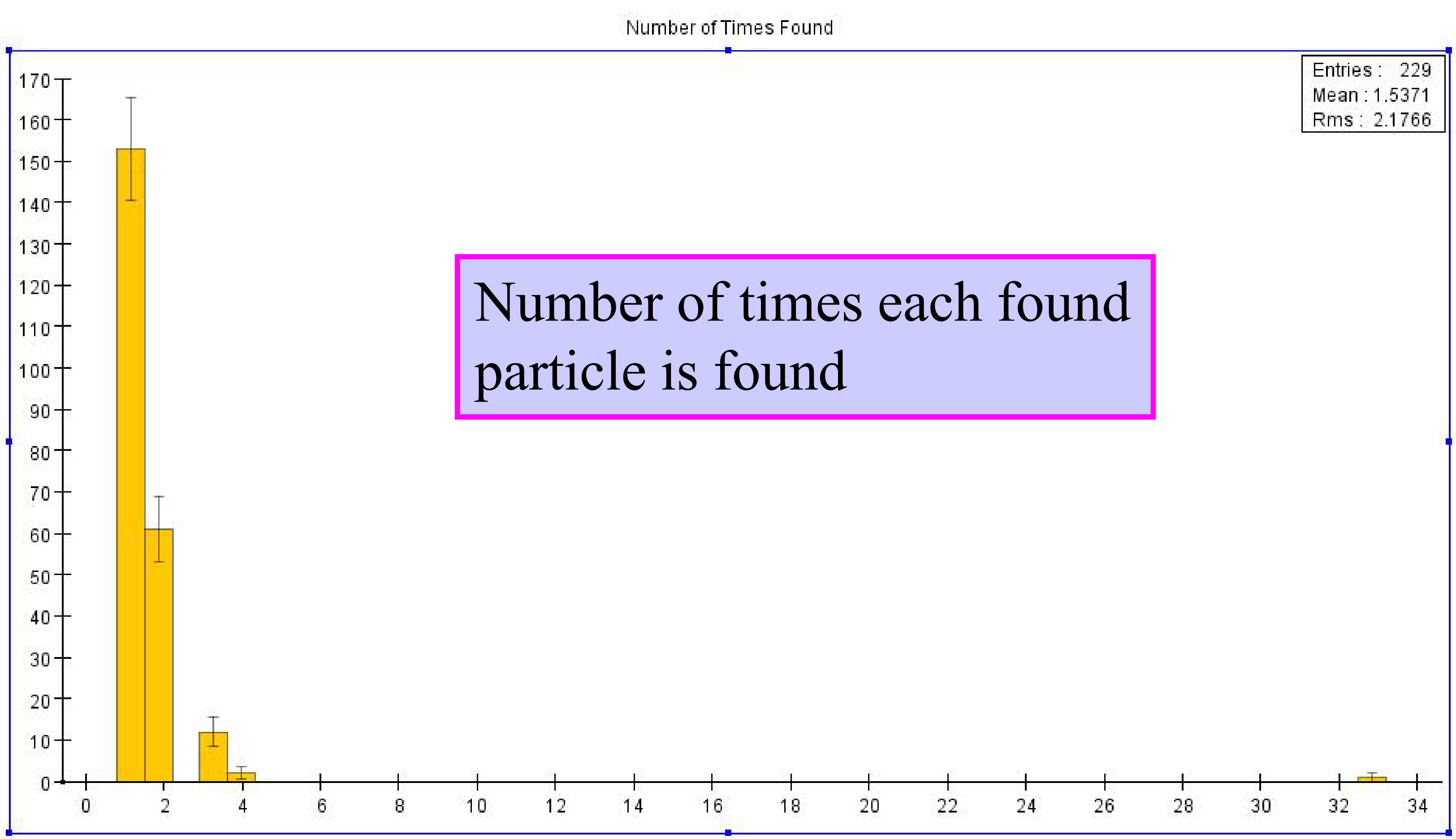
- $P_t > 0.75$
- Radius of origin < 400 mm (require four layers)
- Path Length > 500 mm
- $|\cos\theta| < 0.8$



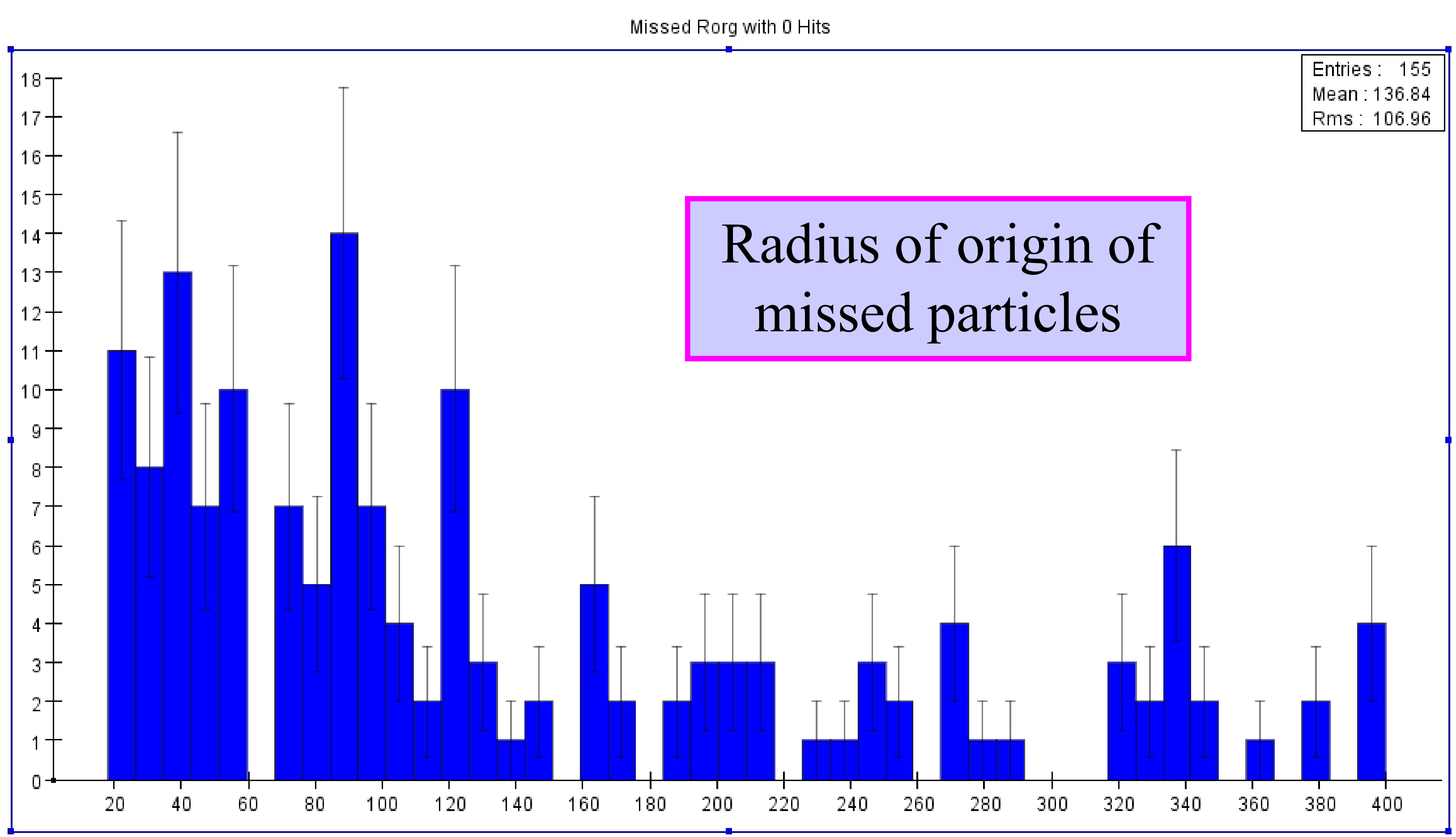
Particle is “found” if it is associated with a track with four or more hits, with at most one hits coming from a different track. All non-associated tracks with p_t>0.75 and DCA < 100mm are labeled “fake”.

	Particles		Fakes
Not Found	175	(46.4%)	--------
Found 4 Hits	88	(23.3%)	270
Found 5 Hits	114	(30.2%)	1
Total	377	(100%)	

Particles can be found more than once… (but there's only one entry per particle in the previous table)



But there's really no reason why the algorithm should be this inefficient for these non-prompt particles



We have a few ideas as to why these are being missed, and are looking into it.

CONCLUSIONS

Extending vertex detector stubs is very efficient for tracks above p_t = 0.5 GeV/c and that originate within the second layer of the VXD

Most of the ~5% of tracks that originate outside the second layer of the VXD originate within the second layer of the central tracker, and may be findable.

We find them with about 30% efficiency now, but believe we can do better.

How much will Z segmentation help? How about tracking calorimeter stubs back in? (Kansas State's GARFIELD package does this with ~30% efficiency)

RANDOM BACK-UP SLIDES

Two Areas of Study

Slepton Mass Reconstruction and Detector Resolution

- Is the information on Slepton masses in the forward region?
- Can we detect it above backgrounds?
- Are our detectors up to the task?

Track Reconstruction with an All-Silicon Detector

- Does the current software reconstruct tracks efficiently in dense jet environments?
- Is the momentum resolution as good as expected from Billior calculations? Why or why not?

THE UCSC SUSY GROUP

Past

Sharon Gerbode (now at Cornell)
Heath Holguin (now a UCSC grad student)
Troy Lau (Now at Michigan)
Paul Mooser (Software engineer)
Adam Pearlstein (now at Colorado State)
Joe Rose

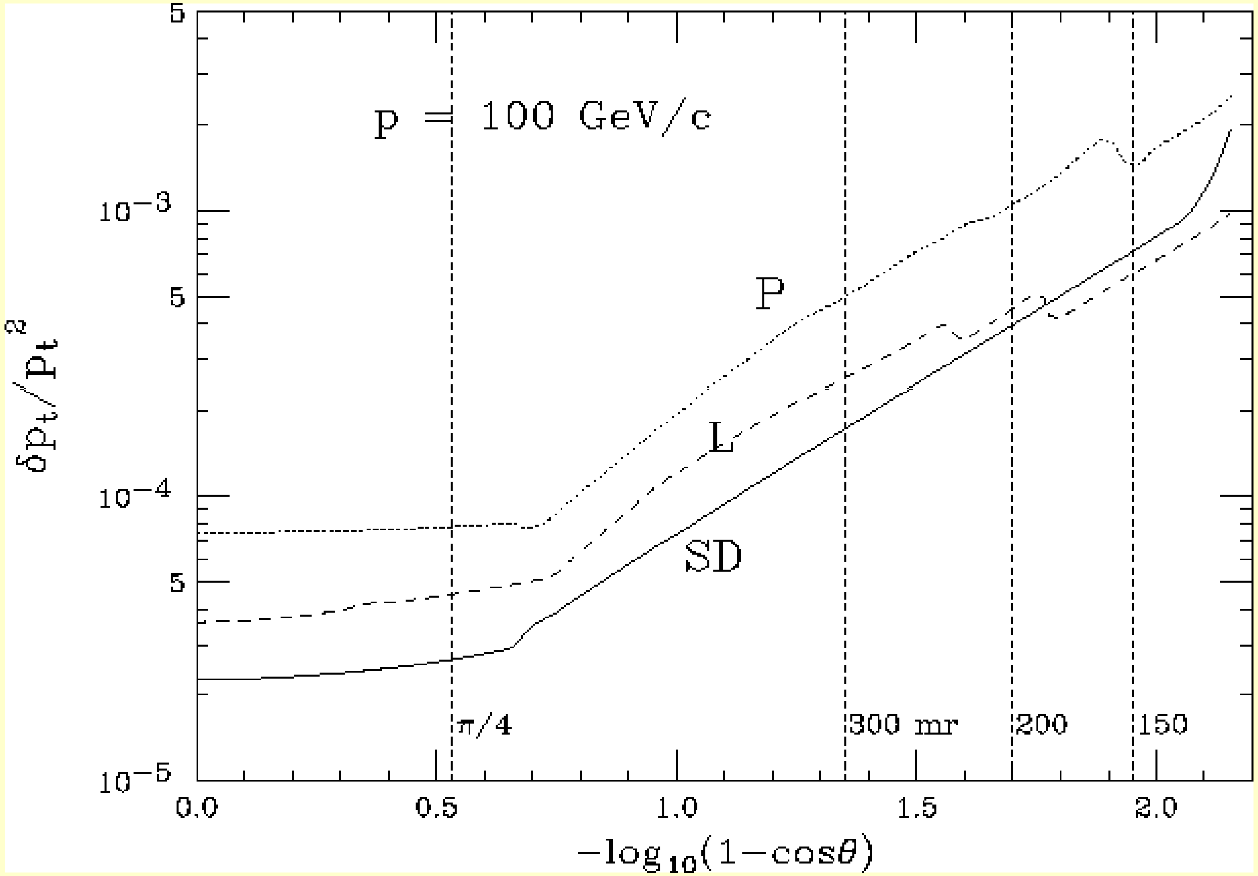
Present

Ayelet Lorberbaum
Eric Wallace
Matthew vegas

Work accomplished by exploiting UCSC's senior thesis requirement…

Motivation

To explore the effects of limited detector resolution on our ability to measure SUSY parameters in the **forward** (|cos(θ)| > .8) region.



SPS 1 Spectroscopy:

At E_{cm} = 1Tev, selectrons and neutralino are light.

Beam/Brehm:
$\sqrt{s_{min}}$=1
$\sqrt{s_{max}}$=1000
γ = .29
s_z = .11 (mm)

1 SPS 1 – mSUGRA scenario

m_0	100 GeV
$m_{1/2}$	250 GeV
A_0	-100 GeV
$\tan\beta$	10
sign μ	+

'typical' scenario
$m_0 = 0.4\, m_{1/2} = -A_0$

1.1 Spectrum & parameters of ISAJET 7.58

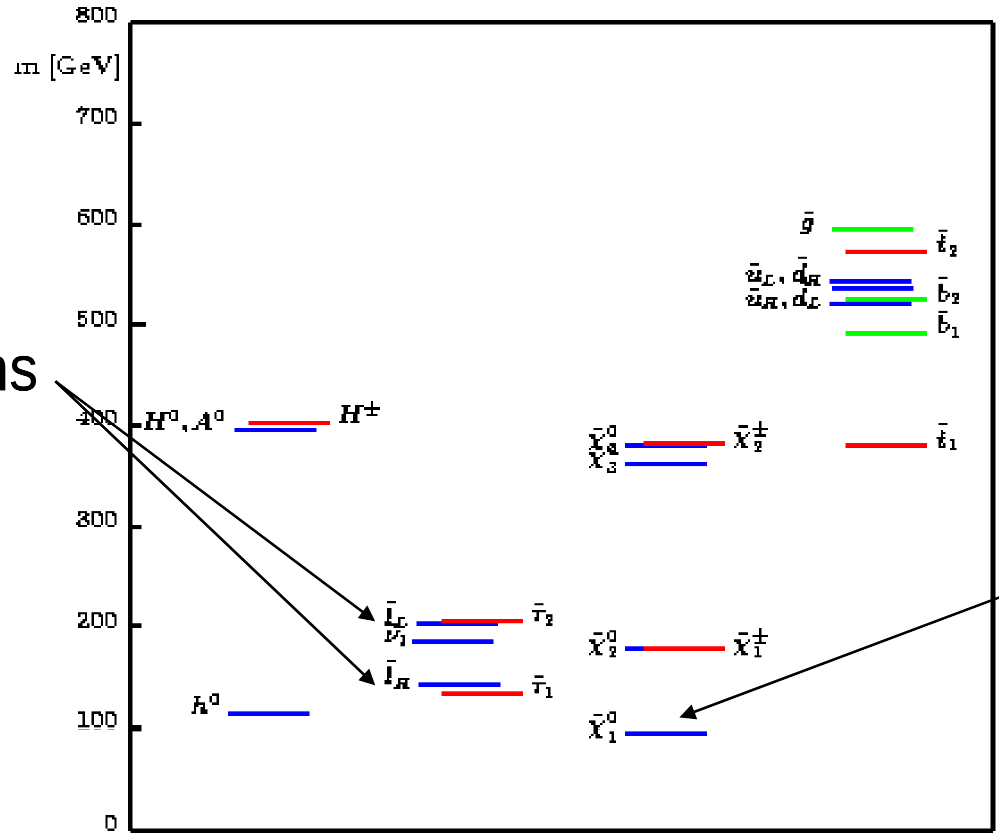
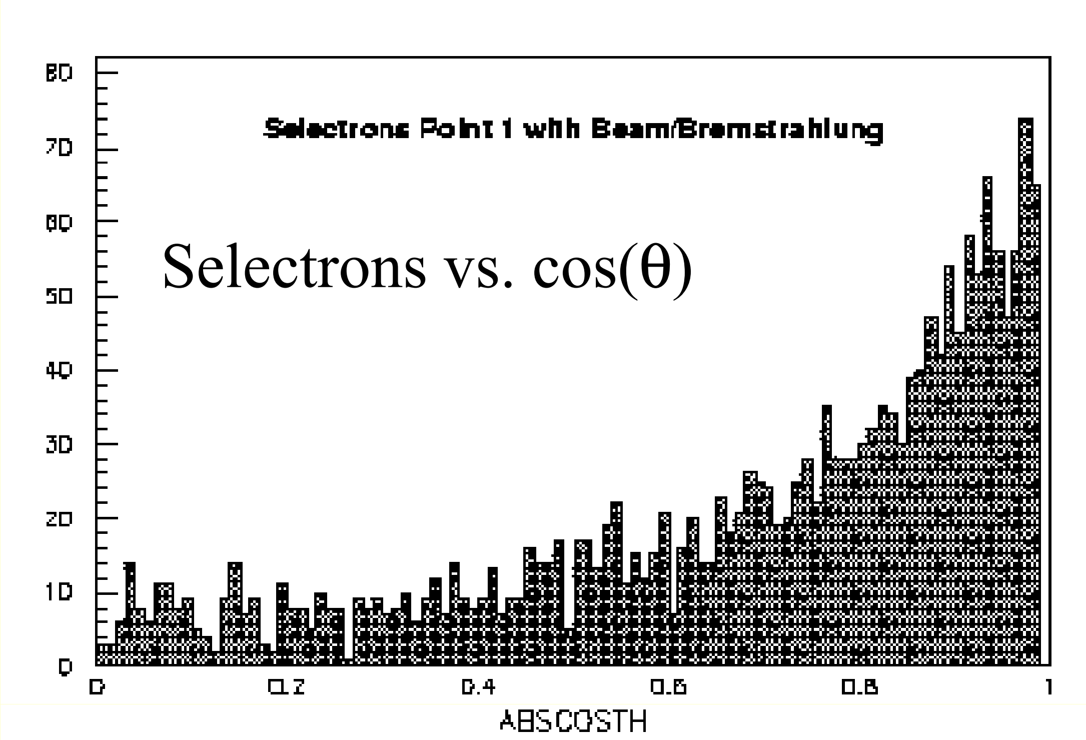
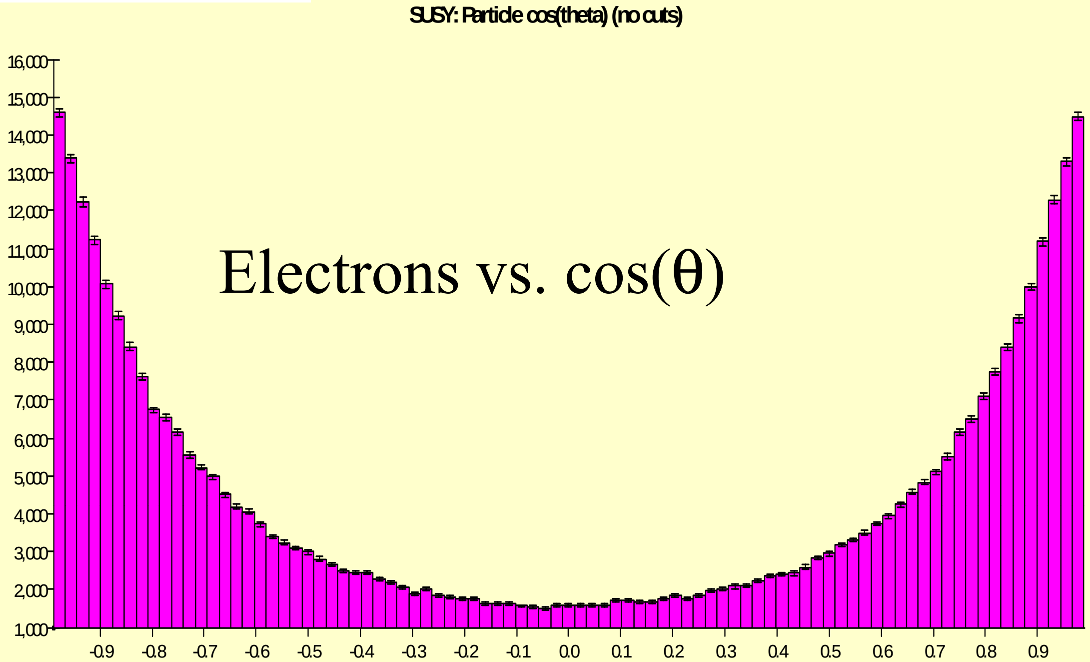


Figure 1: SPS 1 mass spectrum of ISAJET

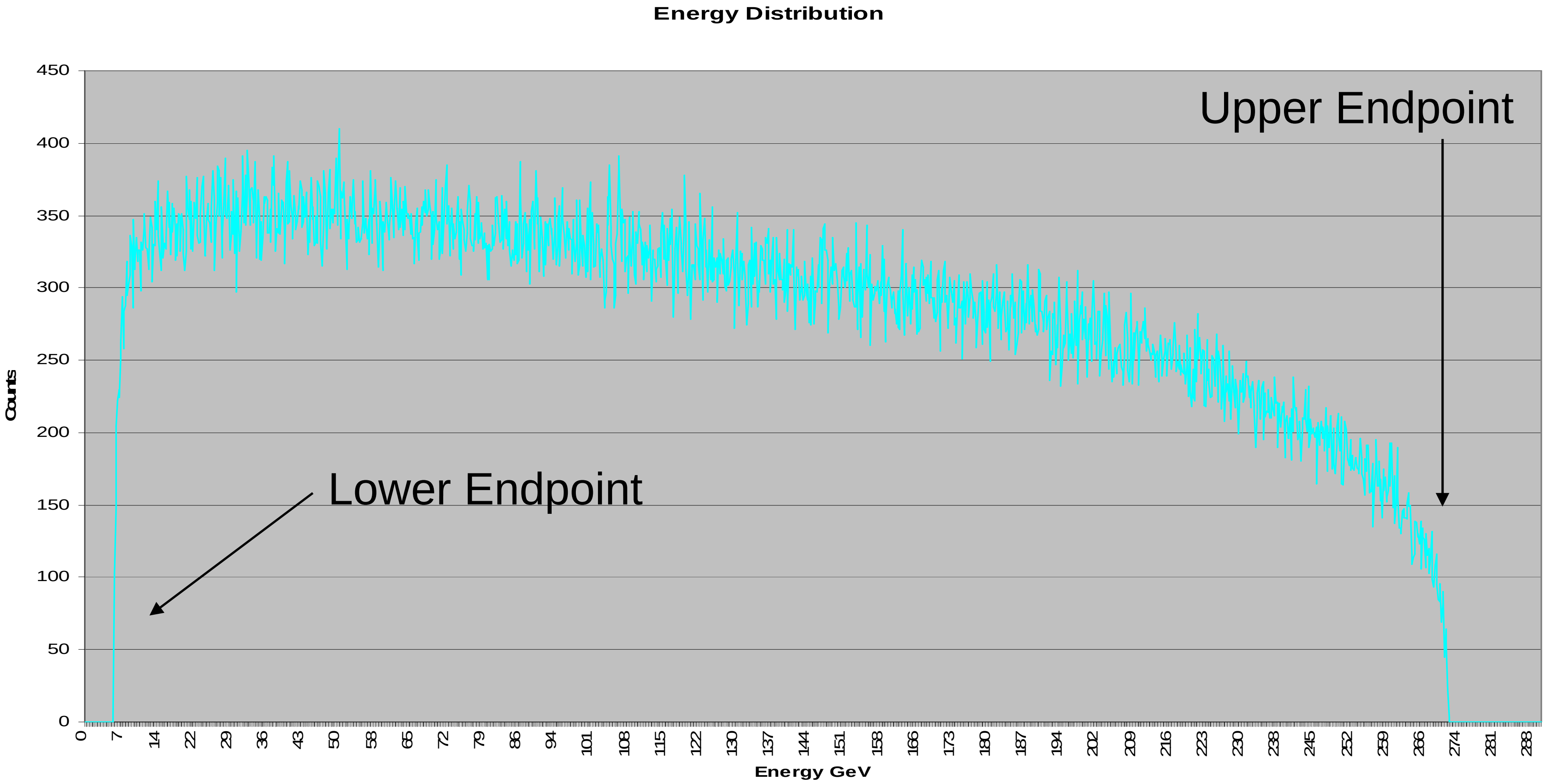


SPS1A at 1 TeV

Roughly ½ of statistics above |cos(θ)| of 0.8, **but**…

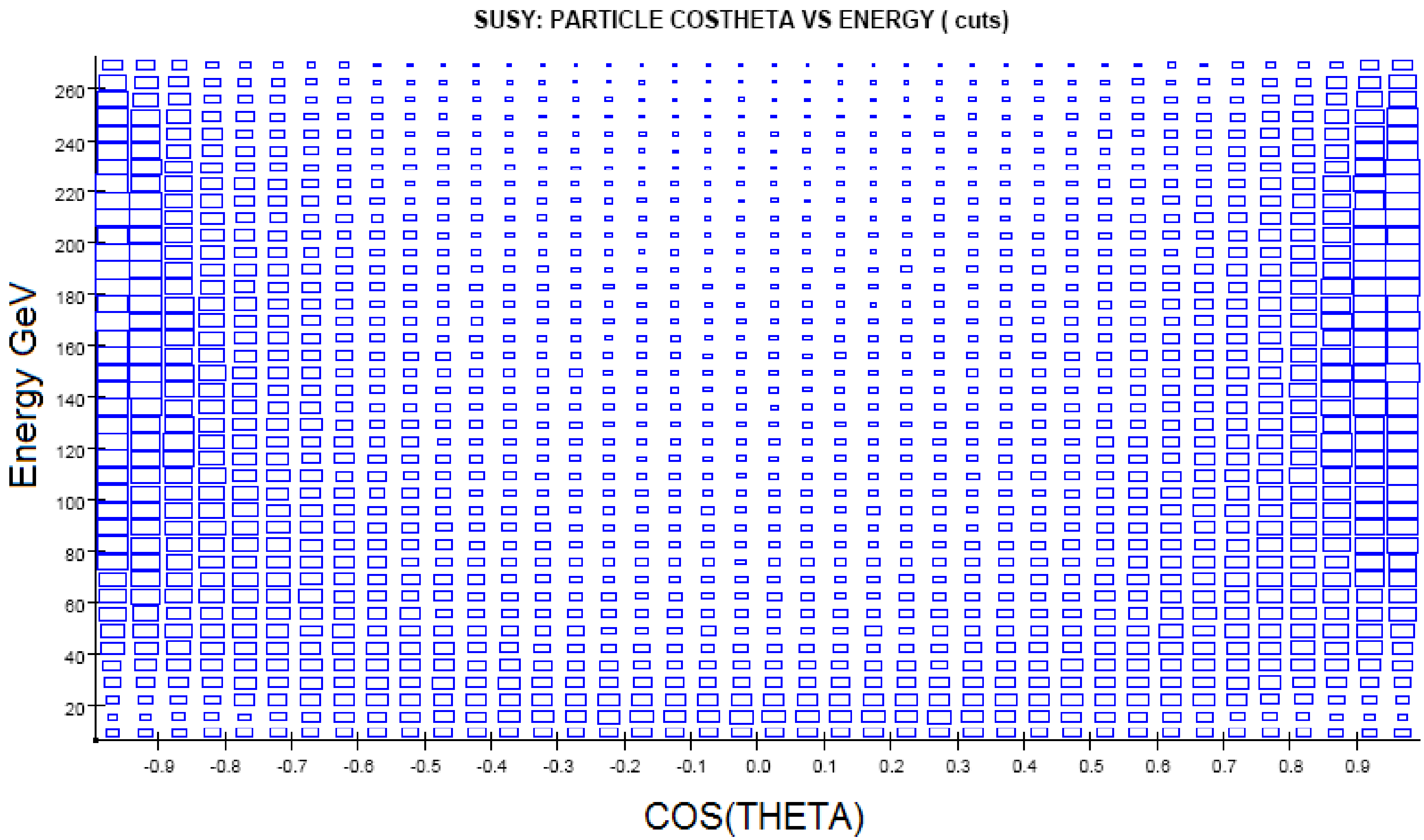


Electron energy distribution with beam/bremm/ISR (.16%). No detector effects or beam energy spread.



- sample electron energy distribution $M_{selectron}$ = 143.112 (SPS1A)

The spectrum is weighted towards higher energy at high $|\cos(\theta)|$, so there's more information in the forward region than one might expect.

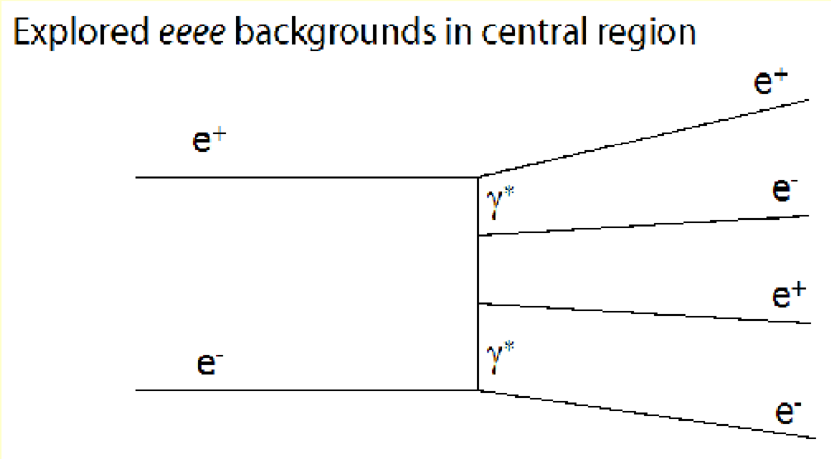


Previous work:

Can one find the selectron signal for $|\cos(\theta)|>0.8$?

Dominant Backgrounds:

$e^+ e^- \rightarrow e^+ e^- e^+ e^-$



$e^+ e^- \rightarrow e^+ e^- \nu \nu$

‘STANDARD’ CUTS

• **Fiducial Cut:** Exactly one final-state positron and one final-state electron pair in |cos(θ)| region of interest, each with a transverse momentum of at least 5GeV. Otherwise the event is discarded.

• **Tagging Cut:** No observable electron or positron in low-angle `tagging’ calorimetry (with coverage of $20\text{mrad} < \theta < 110\text{mrad}$)

• **Transverse Momentum (TM) Cut:** Cuts events where vector sum of transverse momentum for e^+e^- pair is less than 2 * 250GeV * sin (20 mrads)

‘NEW’ CUTS

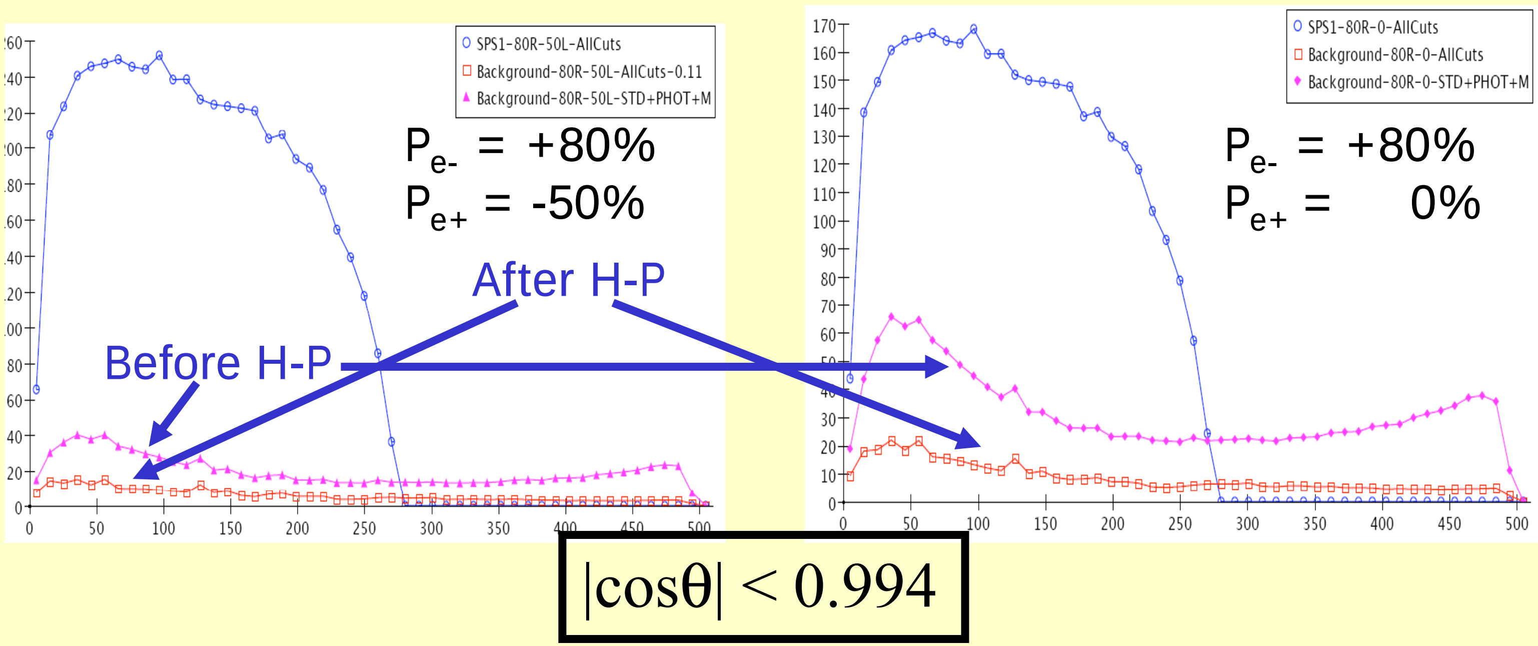
• **Photon Cut:** TM cut eliminates four-electron background except for radiative events. Remove remaining radiative events by looking for radiated photon; i.e., if there is a photon in the tagging region with energy of 20GeV or more.

• **HP Cut:** Removes low-mass, t-channel-dominated eeνν backgrounds while preserving high-mass SUSY signal

Standard Model Backgrounds

After 'photon cut', which eliminates the four-electron background, the dominant background is eeνν. Manipulation of the beam polarization, combined with application of the 'HP Cut' reduces background to minimal levels, even in forward region.

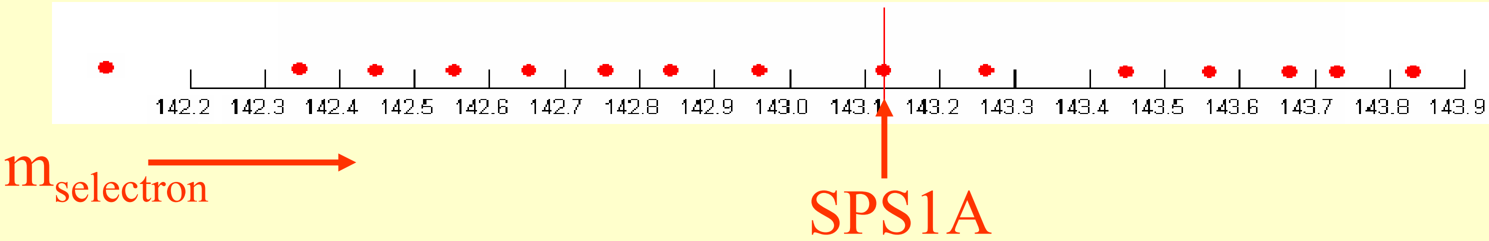
➔ Ignore backgrounds in detector resolution studies.



Fitting the Endpoints for the Selectron Mass

For now, we have done one-dimensional fits (assume χ^0 mass known)

Vary SUSY parameters minutely around SPS1A point so that selectron mass changes while χ^0 mass remains fixed.



Generate 'infinite' (~1000 fb^{-1}) at each point to compare to 115 fb^{-1} data sample; minimize χ^2 vs. $m_{selectron}$ to find best-fit selectron mass.

$$\text{CHI-Squared} = \sum \frac{(w * n_i - m_i / w)^2}{(n_i * w^2 + m_i)}$$

Repeat for 120 independent data samples; statistics from spread around mean rather than directly from χ^2 contour.

Selectron Mass Study Scenarios

12 scenarios were considered:

Detector Resolution

Perfect (no smearing) and SDMAR01

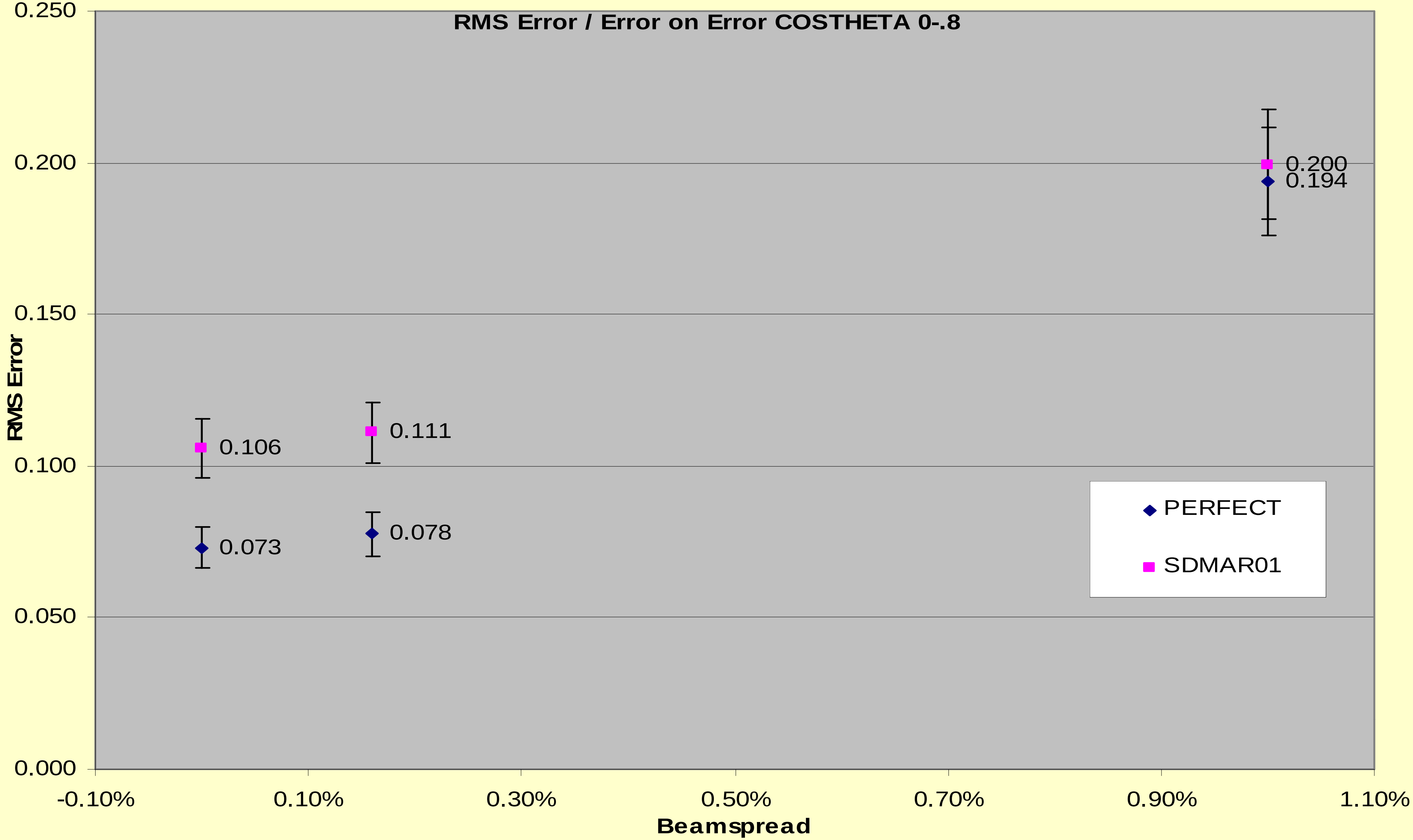
Detector Coverage

$|\cos\theta| < 0.8$ and $|\cos\theta| < 0.994$

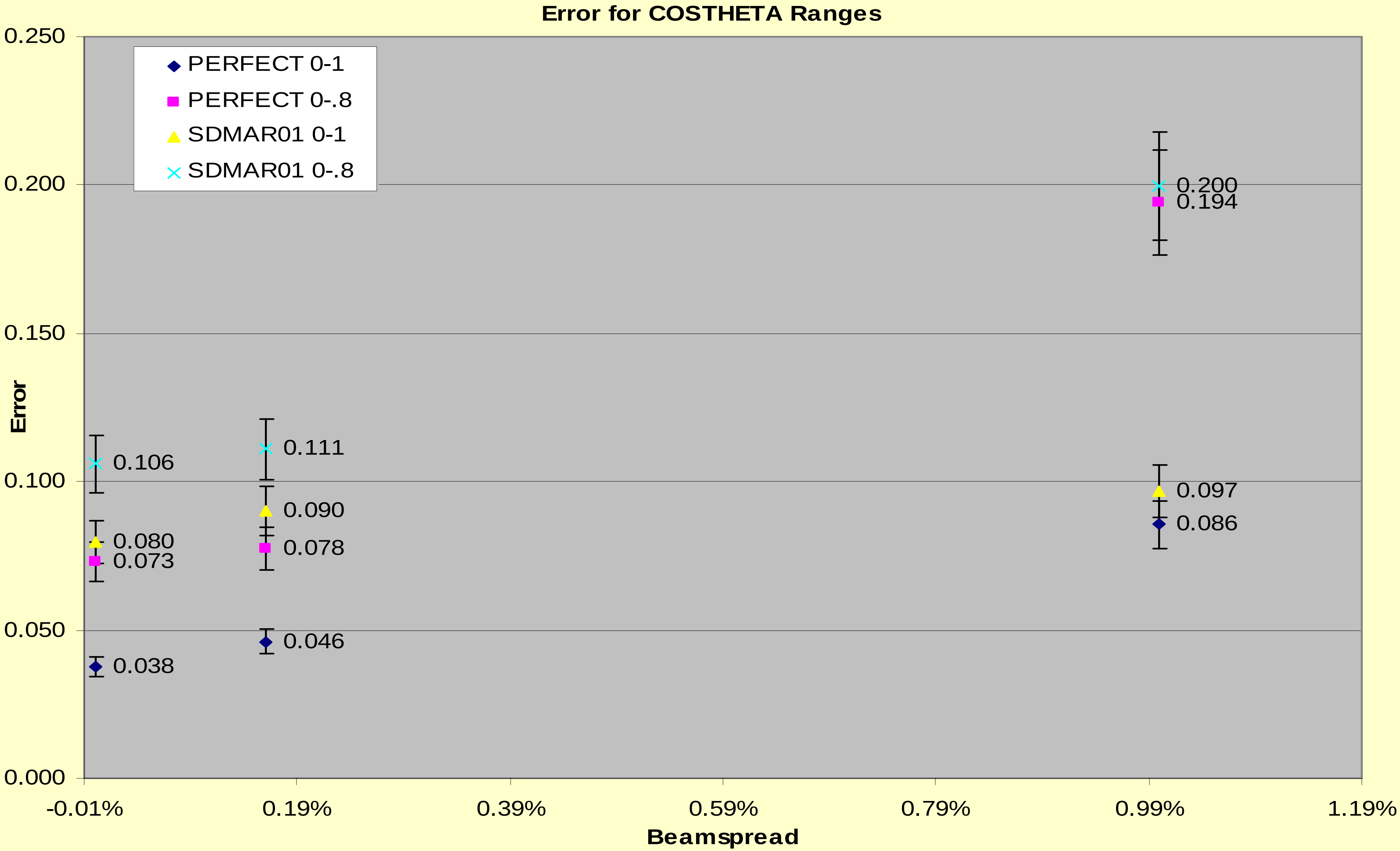
Beam Spread

0%, 0.16%, and 1.0%

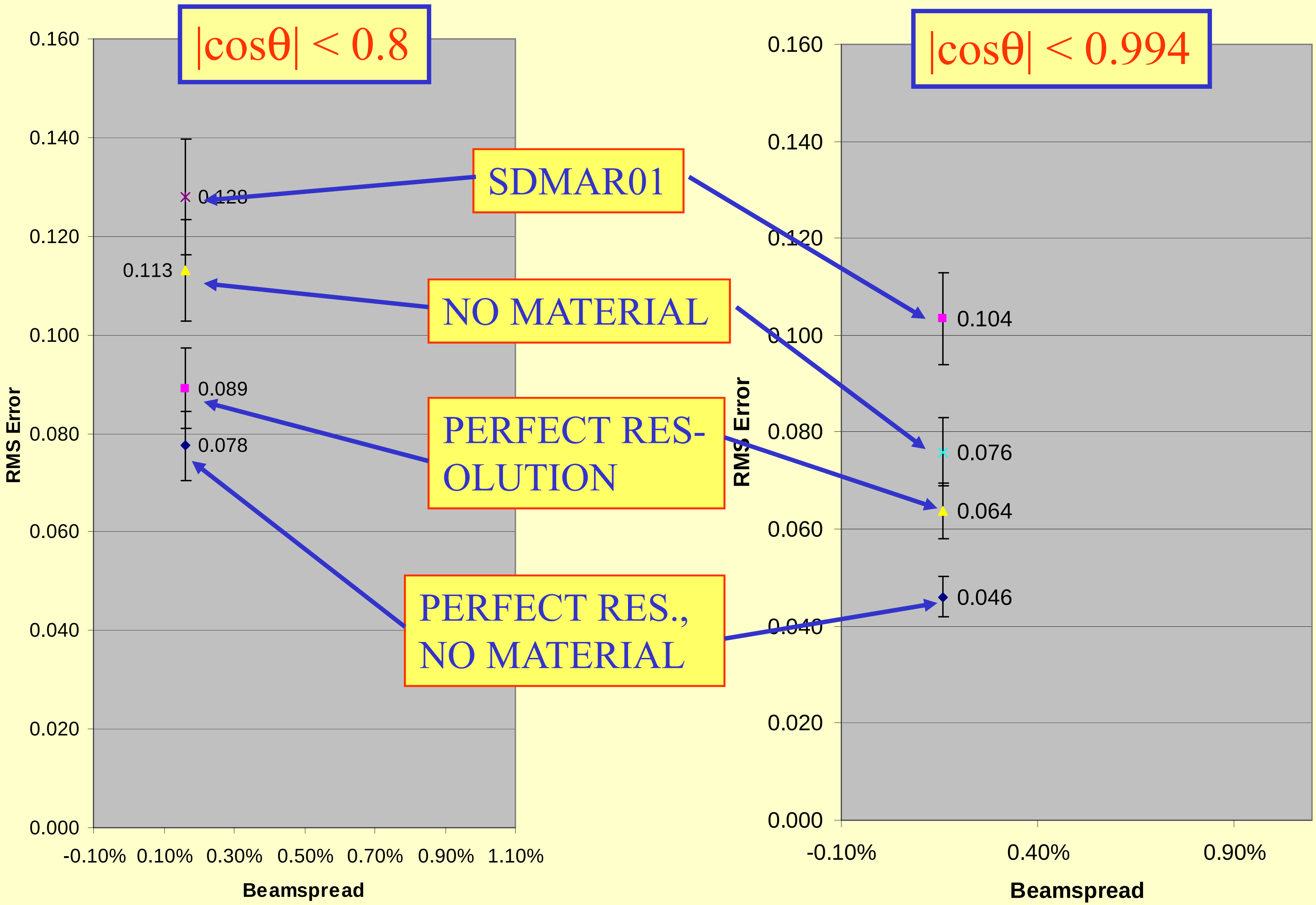
First, just look in the central region (|cosθ| < 0.8)



Now, include the full region (|cosθ| < 0.994)



Is it the point resolution, or the material?



Tentative Conclusions to Draw

1. Due to the stiffening of the spectrum in the forward region, there is a surprising amount of information there. **For this scenario, most of the information on slepton masses lies in the forward ($|\cos\theta| > 0.8$) region.**
2. For cold-technology beamspread (0.14%), SDMAR01 resolution has not reached the point of diminishing returns. The physics seems to be limited by detector resolution. Point resolution is the dominant issue.
3. Any gains that can be made in $p_\perp$ resolution in the forward region would reap large rewards for light sleptons.