UNIVERSITY OF CALIFORNIA SANTA CRUZ

International Linear Collider

Signatures IV Group Report

Momentum Reconstruction, V0 Finding, and Charged Particle ID

ALCPG07 FNAL, Oct 26 2007

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Apologies to 4th Concept (I'm not yet familiar enough to be confident in criticism…)

Our charge was broad – to find signatures that would inform detector design regarding:

- Momentum resolution
- Forward tracking (pattern rec. + resolution)
- Non-prompt tracks (was stated as "V0s")
- Dedicated charged particle ID

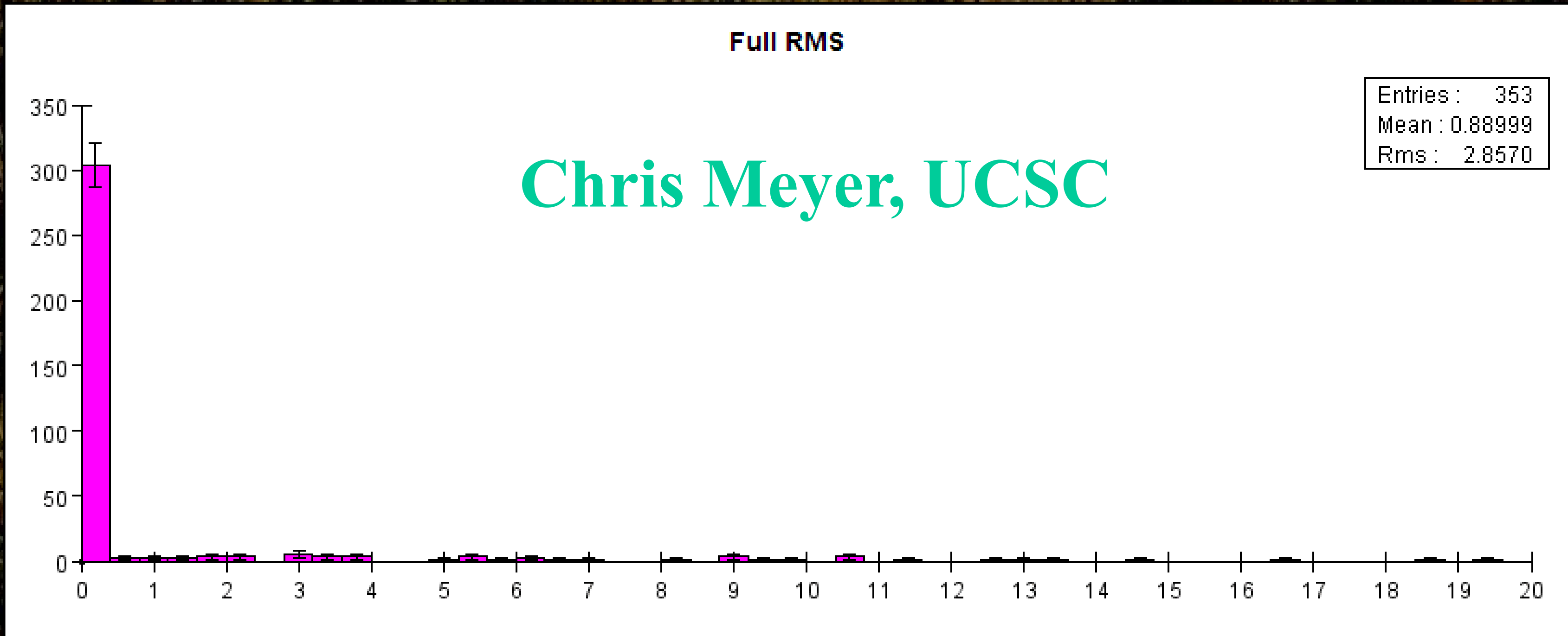
Our discussion centered around the usual candidates: SUSY, SM Higgs, WW but with some new or re-calibrated emphases…

K_S^0 Efficiency and Energy Flow

Form jet/jet mass for $e^+e^- \rightarrow qq$ at $E_{cm} = 500$ GeV

Remove 10% of K_S^0 and form RMS deviation from perfect reconstruction

Find $\sigma_{97\%} = 2.5$ GeV, or 0.5% degradation



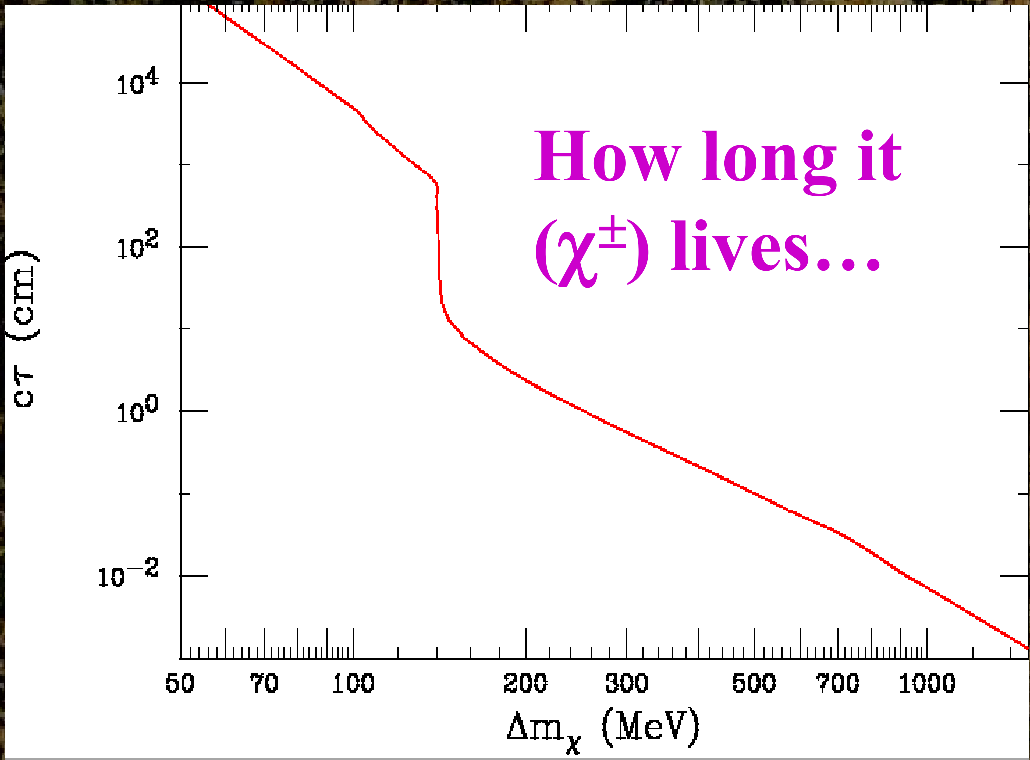
SUSY in Perspective (Tom Rizzo)

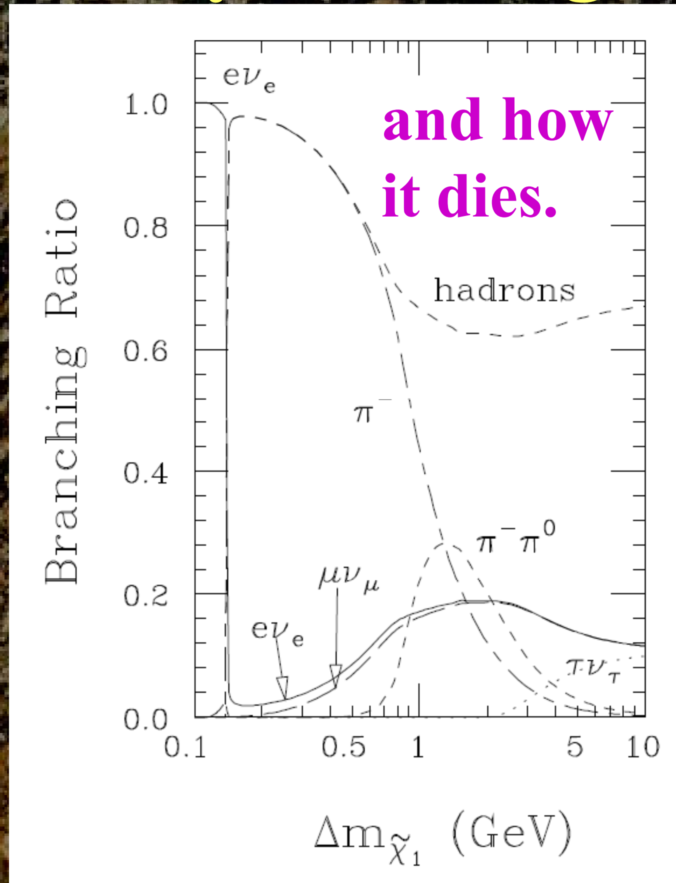
"Can the ILC at 500 GeV distinguish all of the MSSM models (i.e., parameter space points) that were found to give degenerate signatures at the LHC ?? Can the SUSY particles in all these models be observed at ILC?"

"Along the way to answering these questions we needed to perform a general study of signals & backgrounds for hundreds of SUSY models providing a unique opportunity to examine, e.g., signatures, cuts, detector and simulation properties & our basic assumptions/prejudices about SUSY analyses at the ILC."

These "hundreds of models" include some interesting signatures, some of which challenge one or both of the detector concepts…

Anomaly-Mediated Supersymmetry Breaking





Chargino ($\chi^{\pm}$) tends to be nearly degenerate with neutralino (χ^0) ➔ phase-space suppression

For $\Delta M < m_\pi$, model yields effectively stable massive charged particles

Anomaly-Mediated Supersymmetry Breaking with $\Delta M < m_\pi$ (Stable Charged SUSY Partner)

Rizzo et al. have developed a workable selection for E_{cm} = 500 GeV

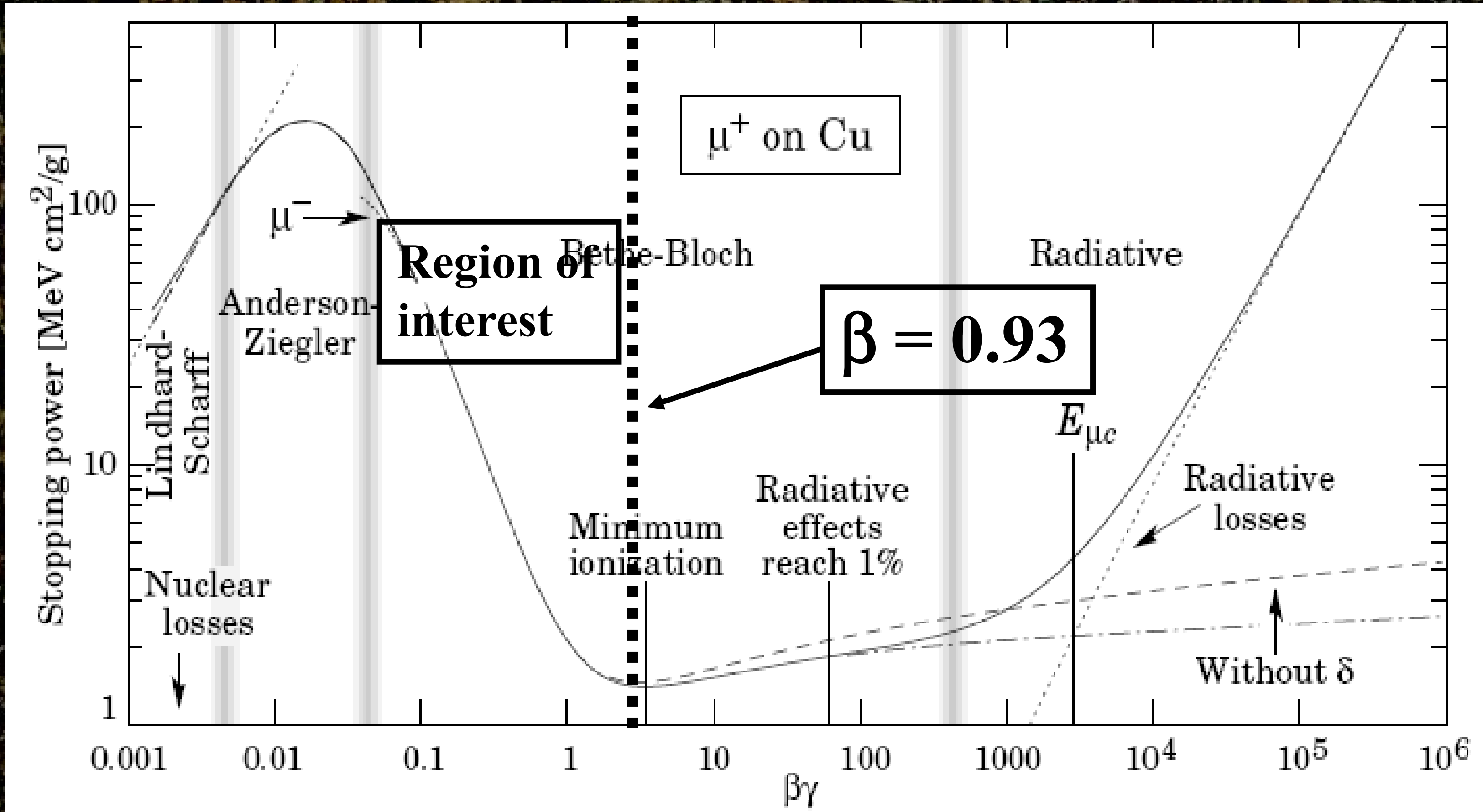
1. 2 massive, charged tracks only
2. no tracks within < 100 mrad
3. $\frac{p}{E} < 0.93$ for both
4. $\sum_{i=1}^{2} E_i > 0.75\sqrt{s}$

   These last two cuts kill any potential muon background. There should not be any background left (aside from detector fakes).

Faster (lighter) ruled out by direct searches (LEP)

The velocity criterion $\beta = p/E < 0.93$ is interesting…

Long-Lived Heavy Charged Particle



But: LHC will probably see or rule out lighter end of spectrum ➔ ILC velocity measurement in $1/\beta^2$ regime

Probably not a motivation for dedicated PID

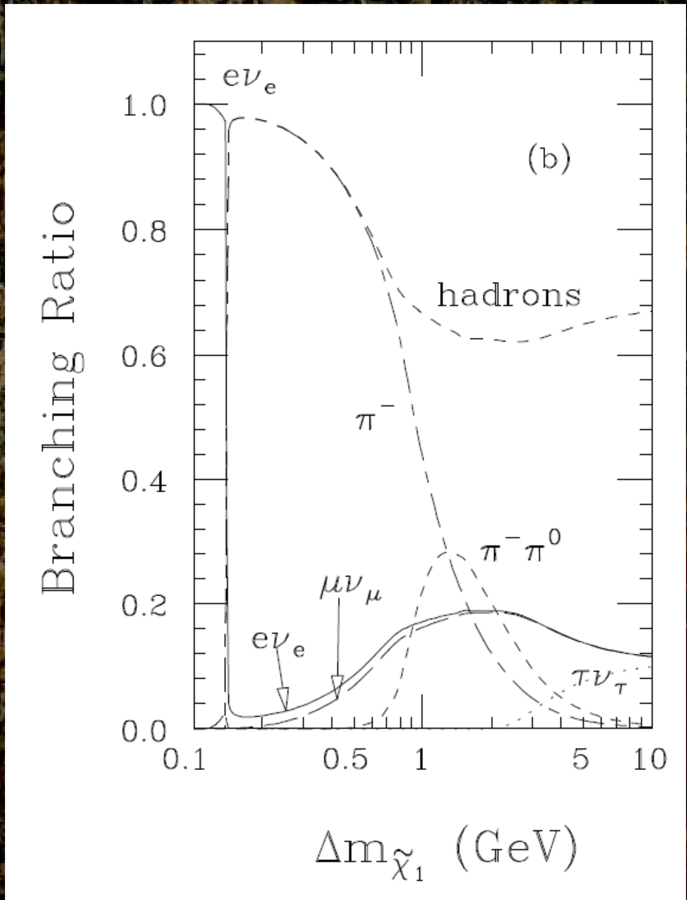
Anomaly-Mediated SUSY with $\Delta M \geq m_\pi$
Soft Isolated Tracks

Typical signature: two unaccompanied charged tracks with $p^{\Delta}_{\perp} \sim 200$ MeV

➔ well motivated, and quite challenging; good to consider?

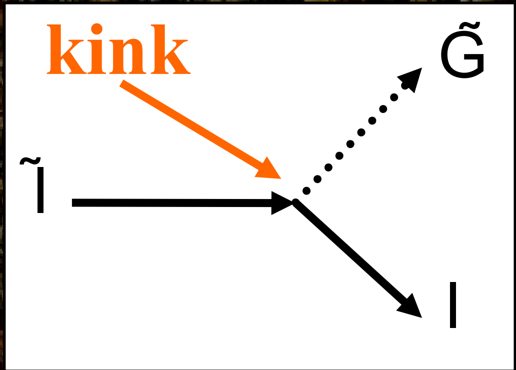
But: could this be done even with perfect tracking?

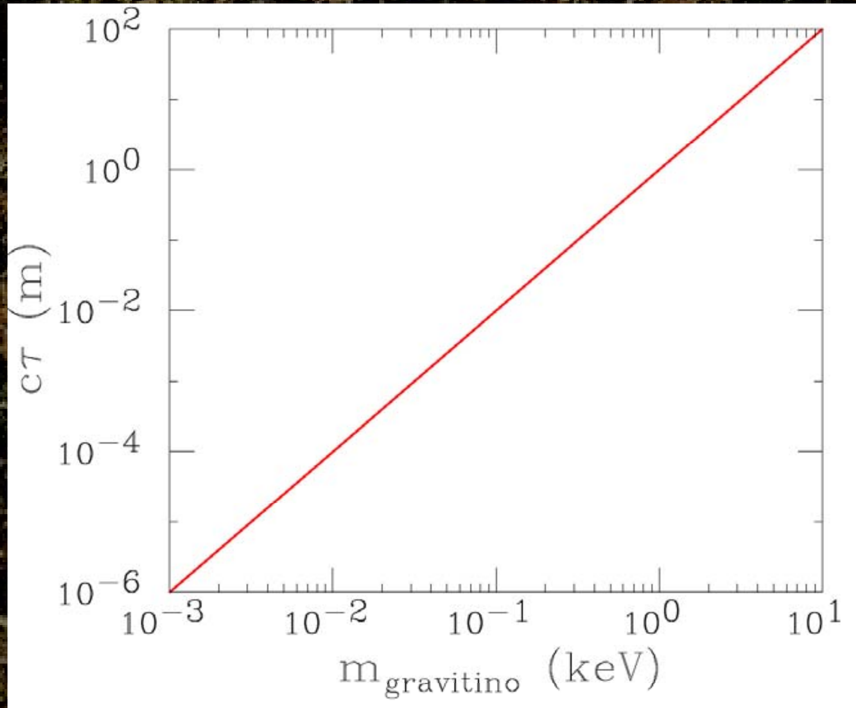
Two-photon backgrounds will be challenging (deflected beam electrons have angle $\sim p^{\Delta}_{\perp}/E_{beam} \sim 10^{-4}$)



Gauge-Mediated Supersymmetry Breaking

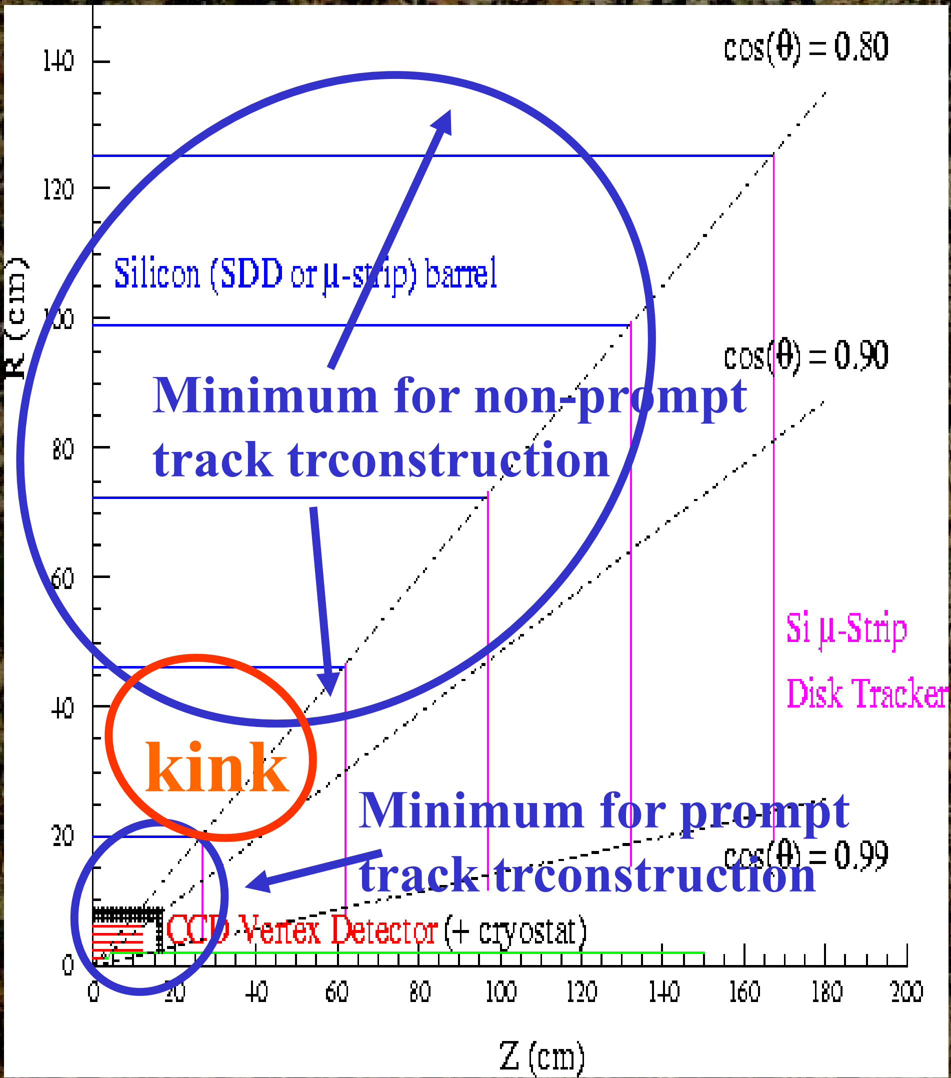
Scenarios with in-flight decay not disfavored by cosmological constraints





For a reasonable range of, e.g., gravitino mass, signature would be kinked track (possible with change in rate of ionization loss

Gauge-Mediated Supersymmetry Breaking II

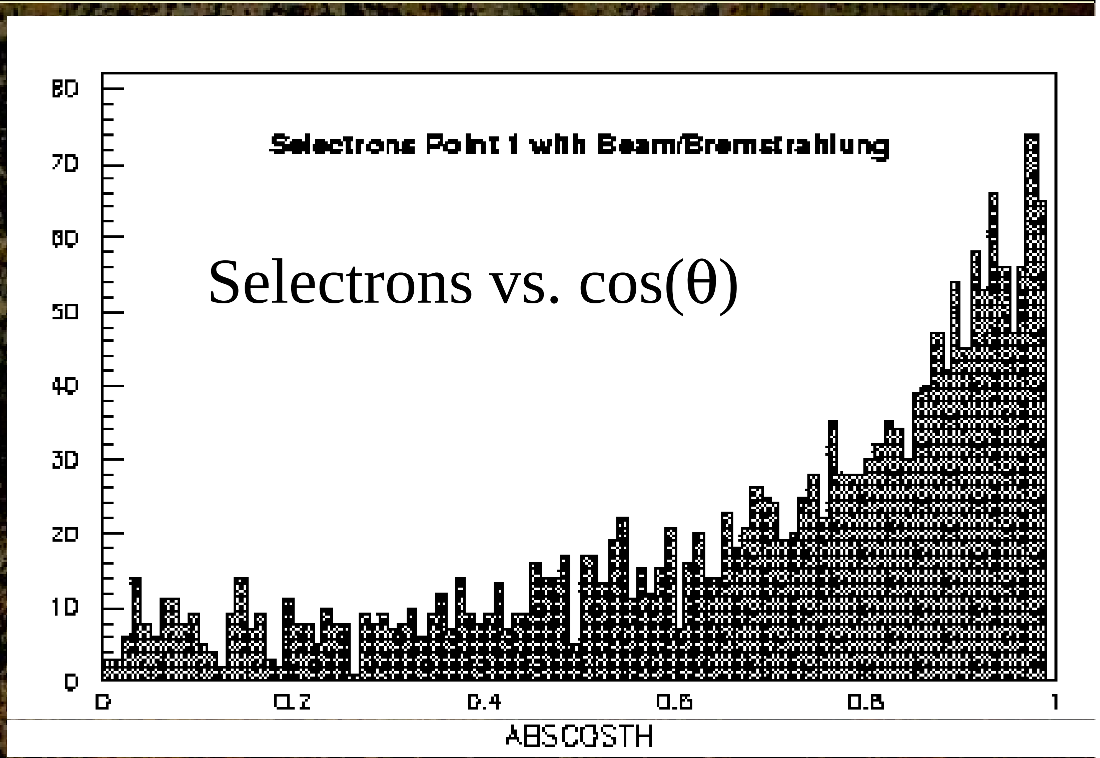


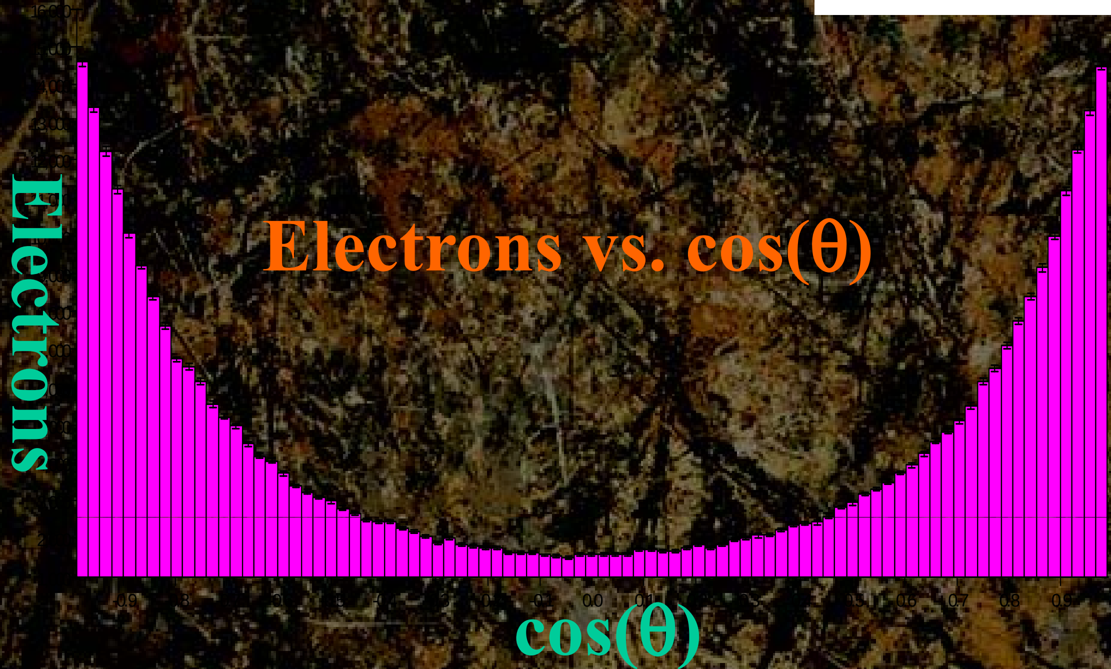
Well-motivated, trac-table signal.

This will challenge SiD, and make group think about layout and z segmentation.

What about gaseous tracking? (For TPC, non-pointing ⇔ out-of-time)

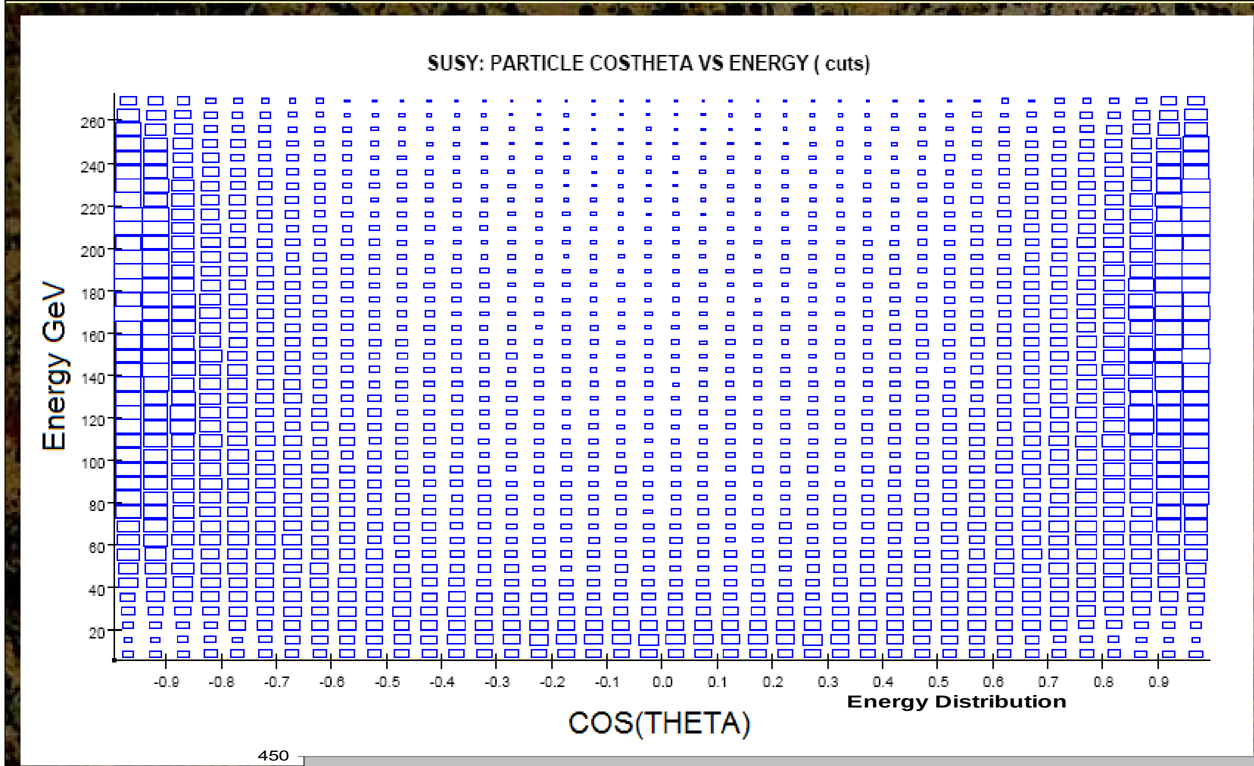
Light Selectrons



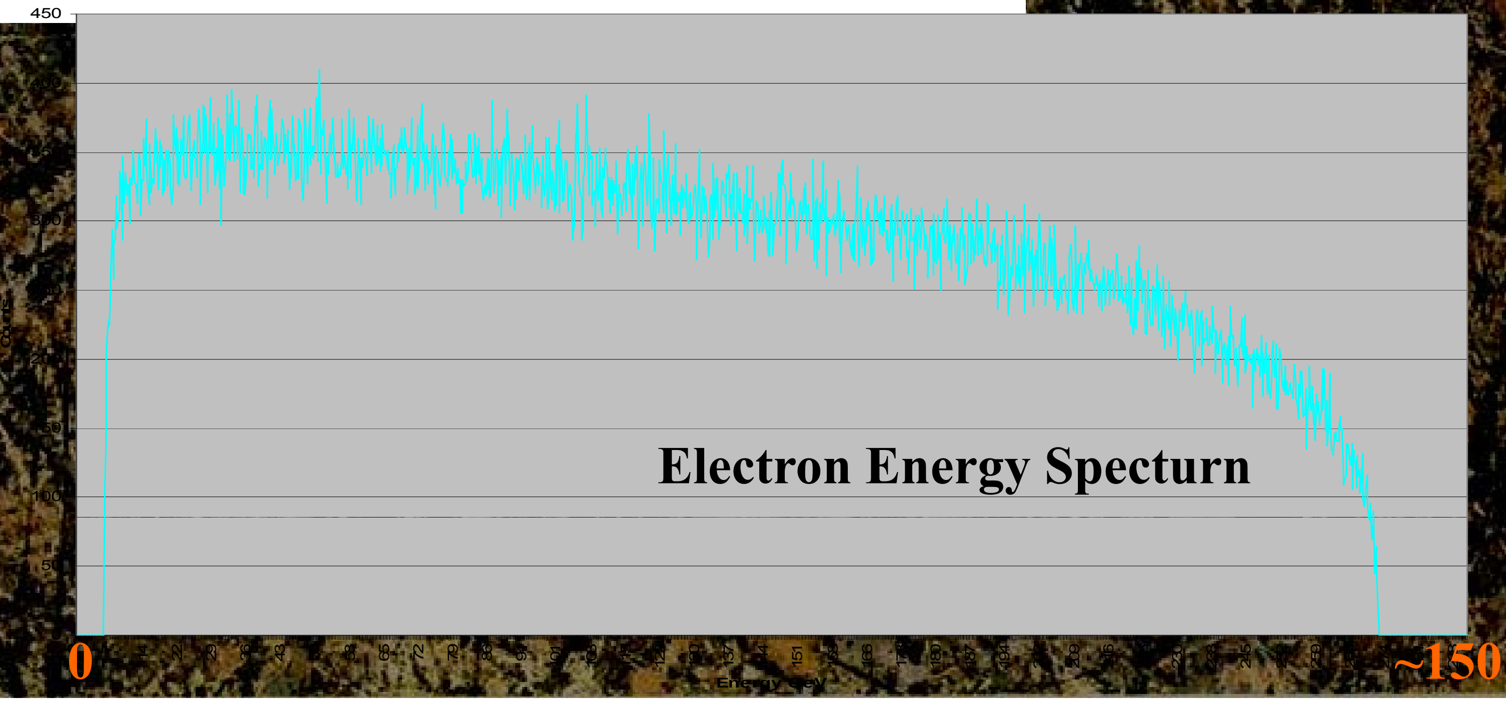


Opening of t-channel pitches majority of signal forward.

But also…

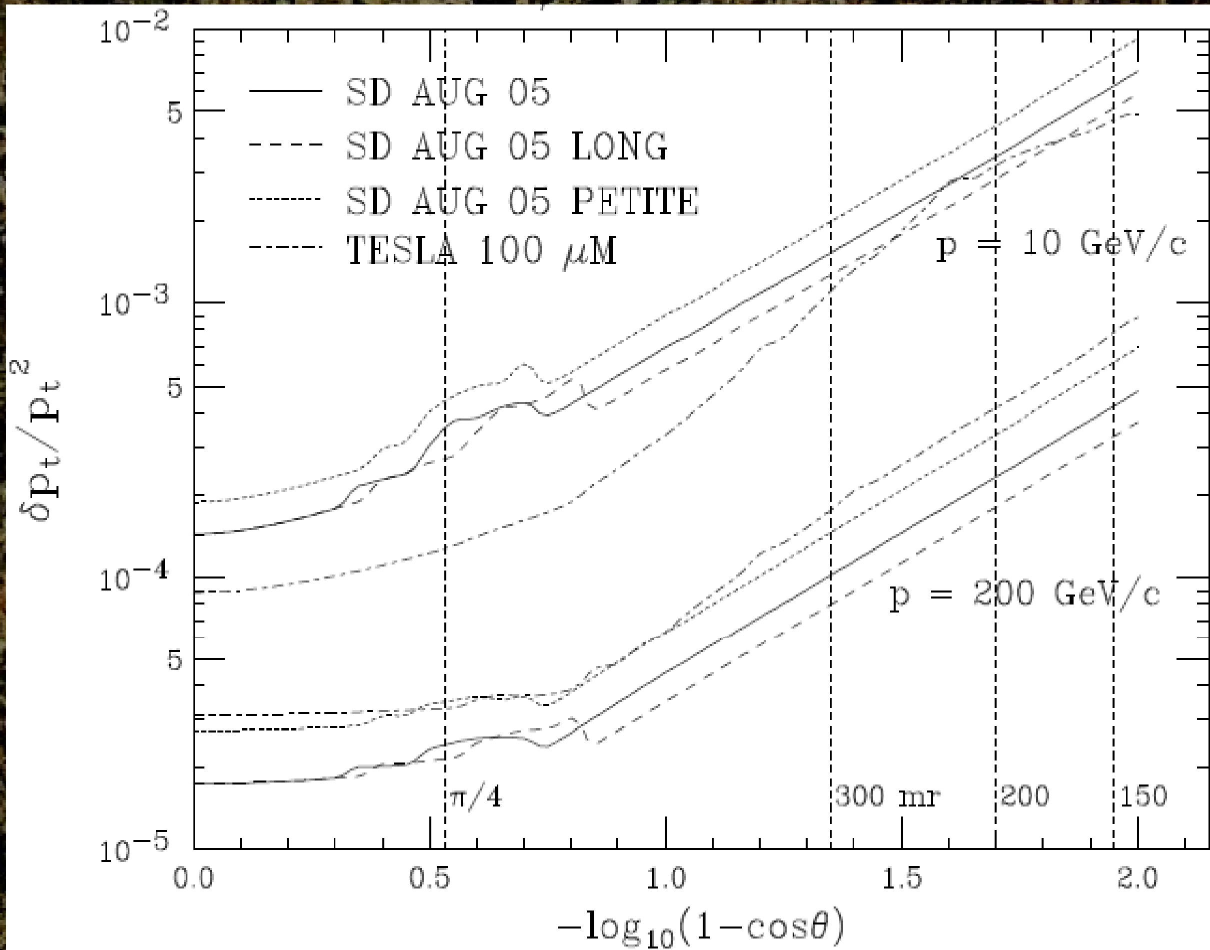


Spectrum is weighted towards higher energy at high |cos(θ)|, increasing stats/ at critical upper endpoint

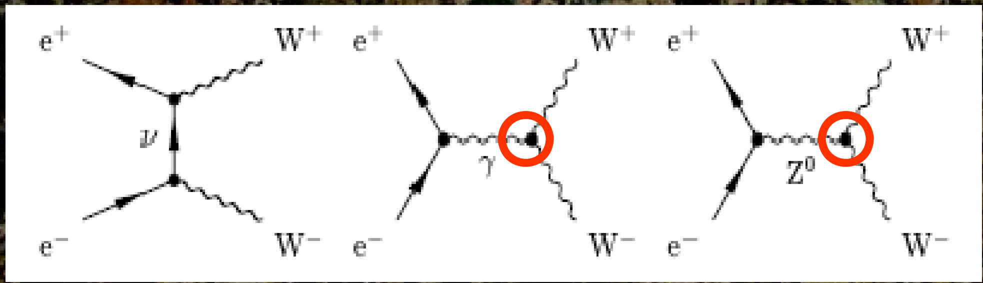


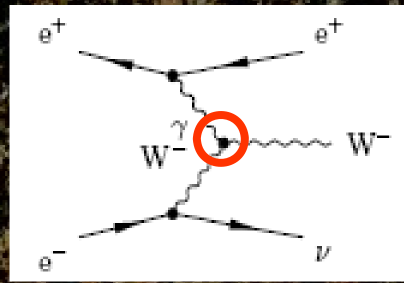
For light SPS1a-like scenario, majority of slepton mass information would be in forward direction

This would challenge any solenoidal-geometry design



Other Interesting Forward Physics: Triple Gauge Boson Couplings



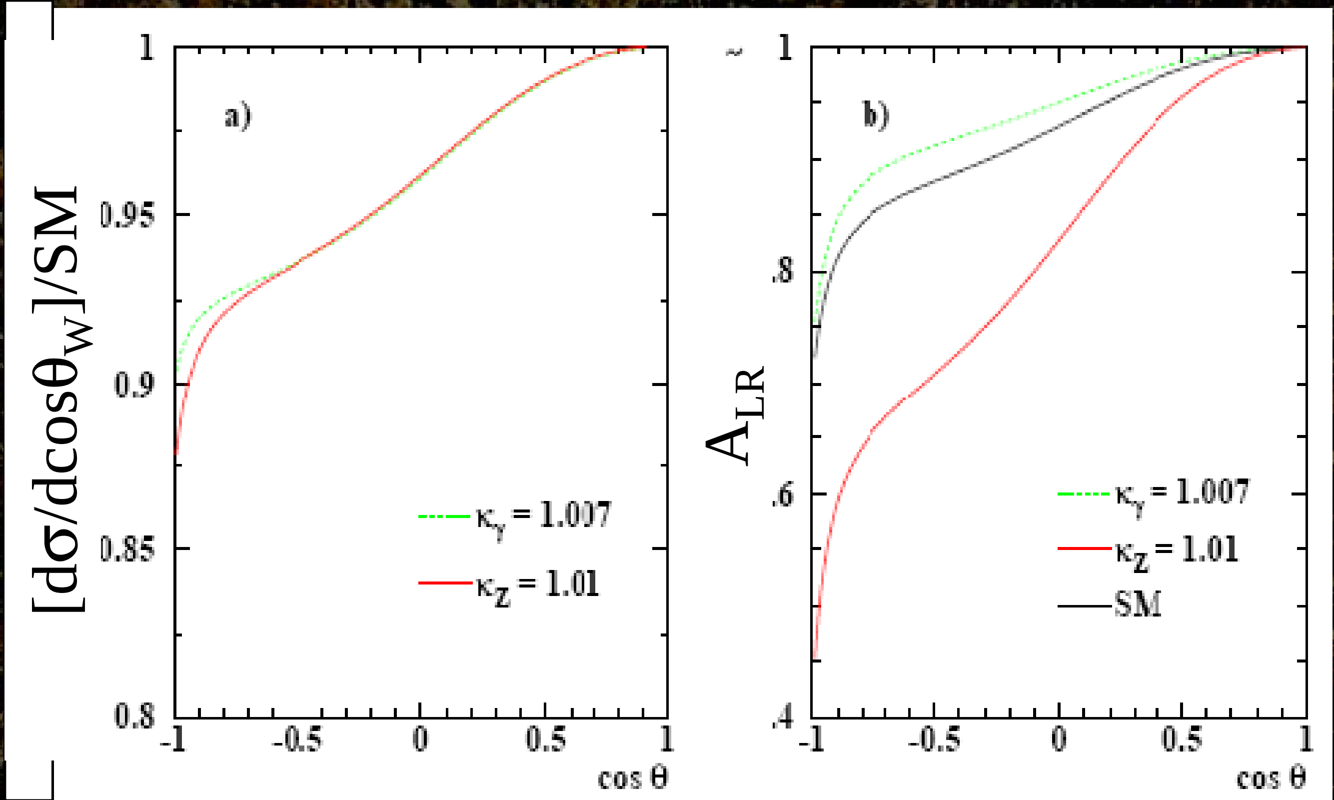


"Double W" Production

Single W

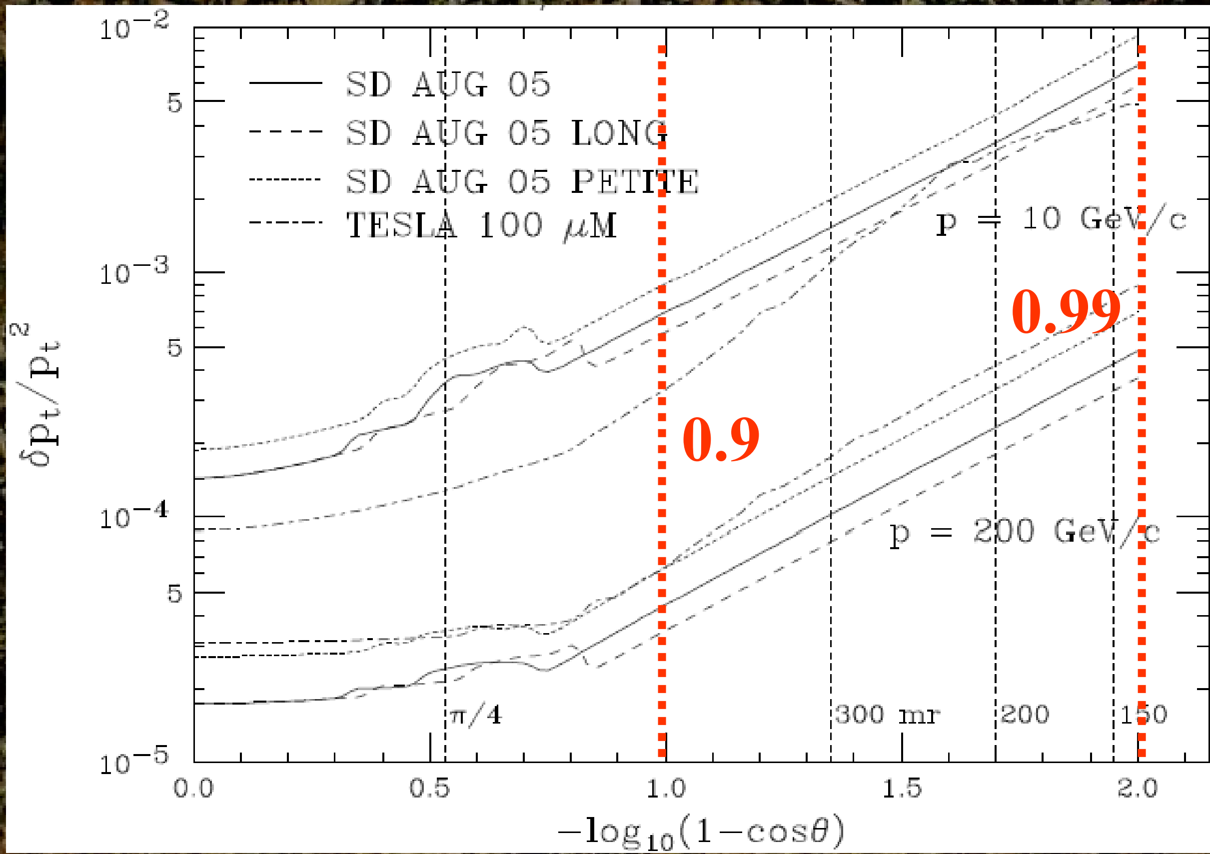
Observation of anomalous couplings would suggest an effective internal structure to gauge bosons, and cause us to re-think the nature of the electroweak scale

Triple Gauge Boson Couplings II



Greatest sensitivity is in far-backward direction (cosθ ~ -1) where t-channel is suppressed

Triple Gauge Boson Couplings III



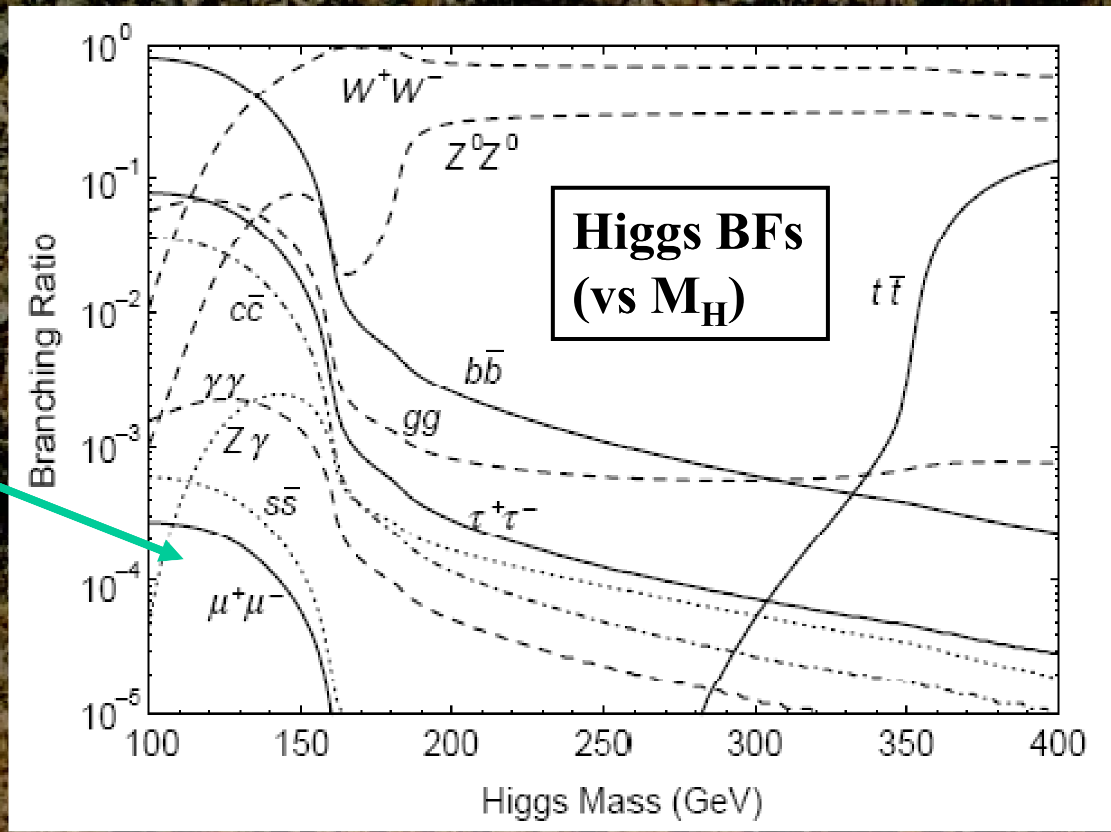
Nominally, tracking (and calorimetry) has coverage, but need full simulation to confirm expectations (backgrounds, boosts)

Precision Momentum Measurement: $H \rightarrow \mu\mu$
(H. Yang, K. Riles, U. Michigan)

$e^+e^- \rightarrow HZ$

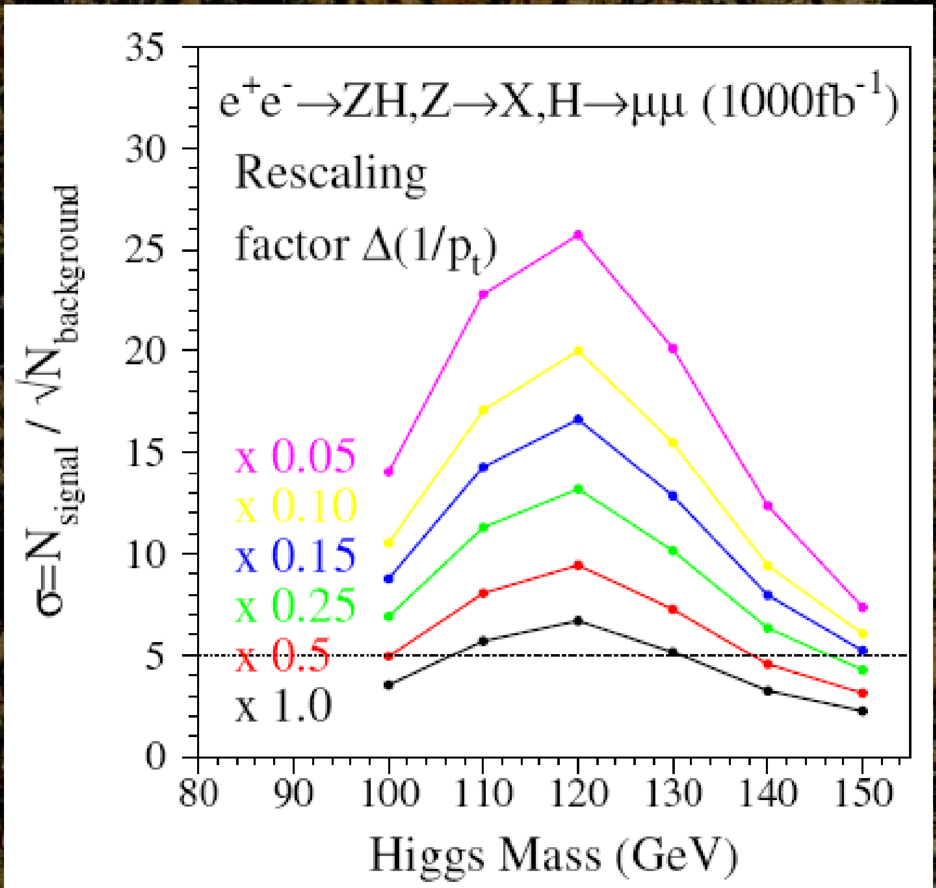
$\quad \hookrightarrow X$

$\quad \hookrightarrow \mu^+\mu^-$



Since light Higgs is narrow, speculate that $M_{\mu\mu}$ resolution is limited by tracker resolution…

H→ μμ Significance vs. Tracker resolution



Rescaling factor relative to SiDMar01:

$$\Delta(1/p_\perp) = a \oplus b/p_\perp$$

$$a = 2 \times 10^{-5}$$

$$b = 7 \times 10^{-4}$$

Sensitivity improves well beyond 2×10^{-5}

Best shot at 2nd gen. fermion? (H. Logan)

What About Dedicated Charged Particle ID?

Can be useful in flavor & charge separation

- $H \to bb$ vs. $H \to cc$
- Forward-backward asymmetries in

  $e^+e^- \to Z' \to ff$

μ,K indicative of heavy flavor cascade, and tag charge

Probably best to study via vertex recon-struction Neural Net; no group has yet taken this on.

Are we missing some compelling motivation?

Summary (I of III)

There are some well-motivated signatures that will challenge one or both detectors

It's not clear that experimentalists or theorists have thought them through adequately.

SUSY

- AMSB leads to events with a few soft tracks – must understand backgrounds before designing tracking for this signature
- GMSB leads to tractable signal with kinked tracks

Artwork courtesy J. Pollock

Summary (II of III)

Forward Tracking

• Light sleptons present opportunity/challenge for momentum resolution of forward tracker

• WW production might be good place to confirm reconstruction capabilities

Momentum Resolution

• $H \rightarrow \mu\mu$ presents new challenge to momentum resolution in central detector

Dedicated Charged Particle ID

• Tagging contribution unexplored. Are we missing anything?

Summary (III of III)

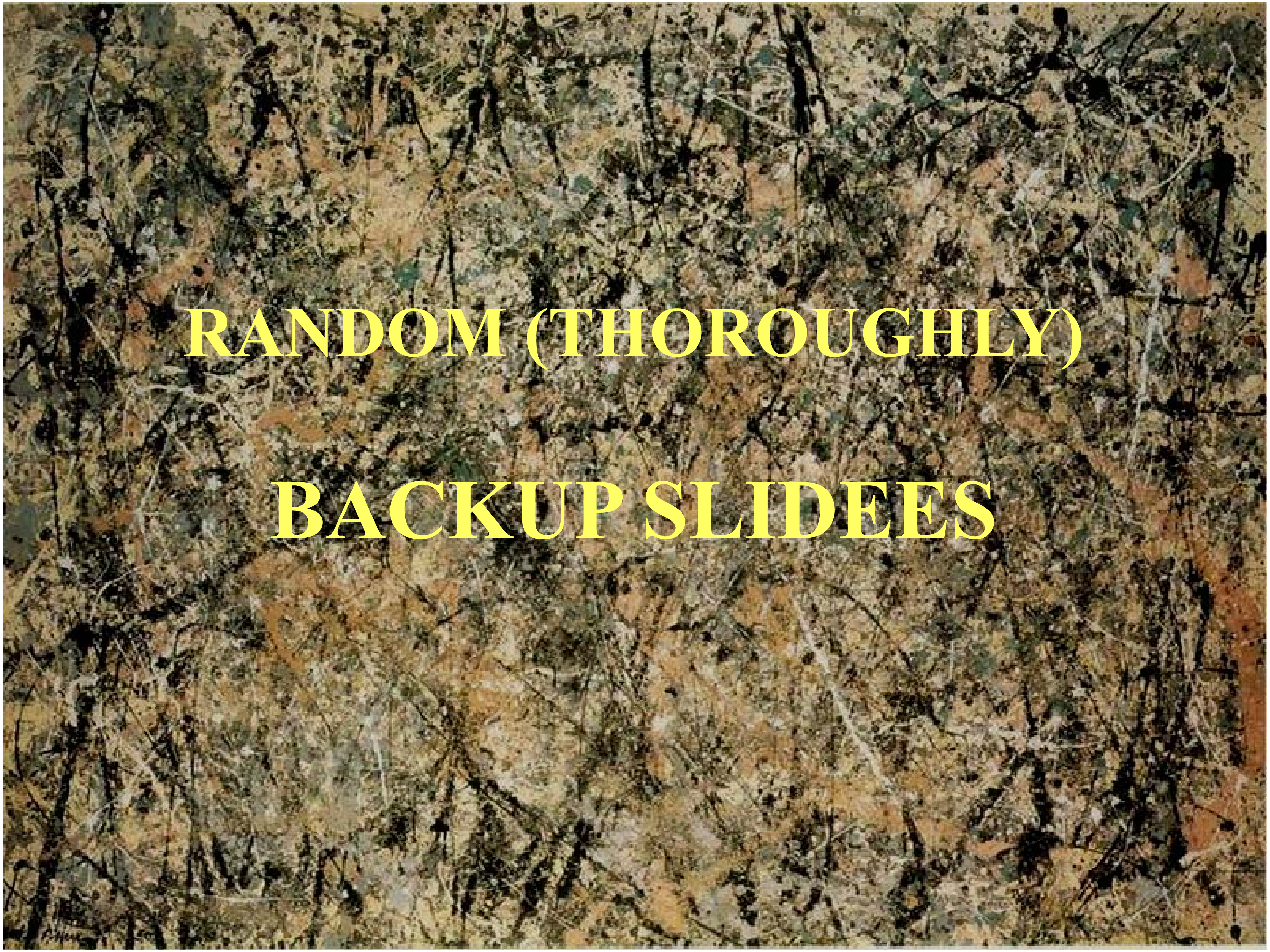
The "signatures" format worked well for our group; time was too short. Ideally, we should keep in touch. For example…

It would be quite possible to improve the $p_\perp \to \infty$ momentum resolution by x5. But would the cost ($$$, compromising other physics) be worth it?

It's not enough for theorists to propose and experimentalists to study: some dialog is needed for optimization.

"Signatures" was a good start. What next?

Artwork courtesy J. Pollock



RANDOM (THOROUGHLY)

BACKUP SLIDEES

Battaglia et al. Benchmarks (2006)

0. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^0, $K^{\pm}$, K^0_S, γ, $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV
1. $e^+e^- \rightarrow f\bar{f}$, $f = e, \tau, u, s, c, b$ at $\sqrt{s}$=0.091, 0.35, 0.5 and 1.0 TeV;
2. $e^+e^- \rightarrow Z^0h^0 \rightarrow \ell^+\ell^-X$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
3. $e^+e^- \rightarrow Z^0h^0$, $h^0 \rightarrow c\bar{c}, \tau^+\tau^-, WW^*$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
4. $e^+e^- \rightarrow Z^0h^0h^0$, $M_h = 120$ GeV at $\sqrt{s}$=0.5 TeV;
5. $e^+e^- \rightarrow \tilde{e}^+_R\tilde{e}^-_R$ at Point 1 at $\sqrt{s}$=0.5 TeV;
6. $e^+e^- \rightarrow \tilde{\tau}^+_1\tilde{\tau}^-_1$, at Point 3 at $\sqrt{s}$=0.5 TeV;
7. $e^+e^- \rightarrow \tilde{\chi}^+_1\tilde{\chi}^-_1/\tilde{\chi}^0_2\tilde{\chi}^0_2$ at Point 5 at $\sqrt{s}$=0.5 TeV;

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

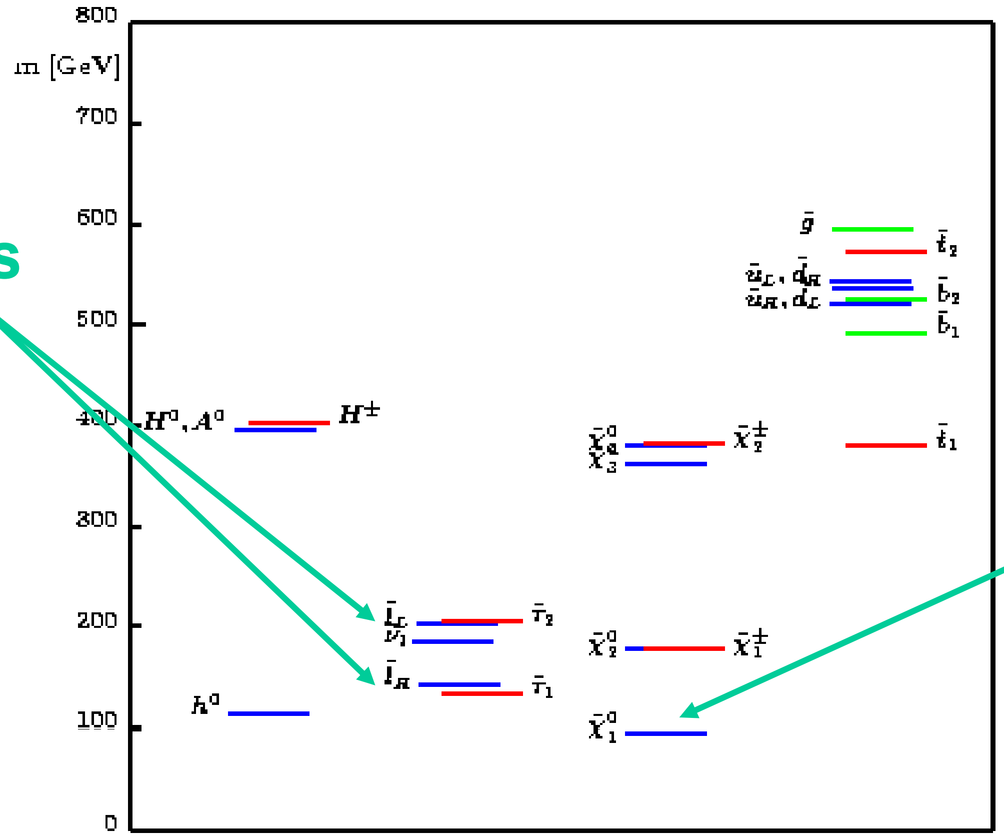
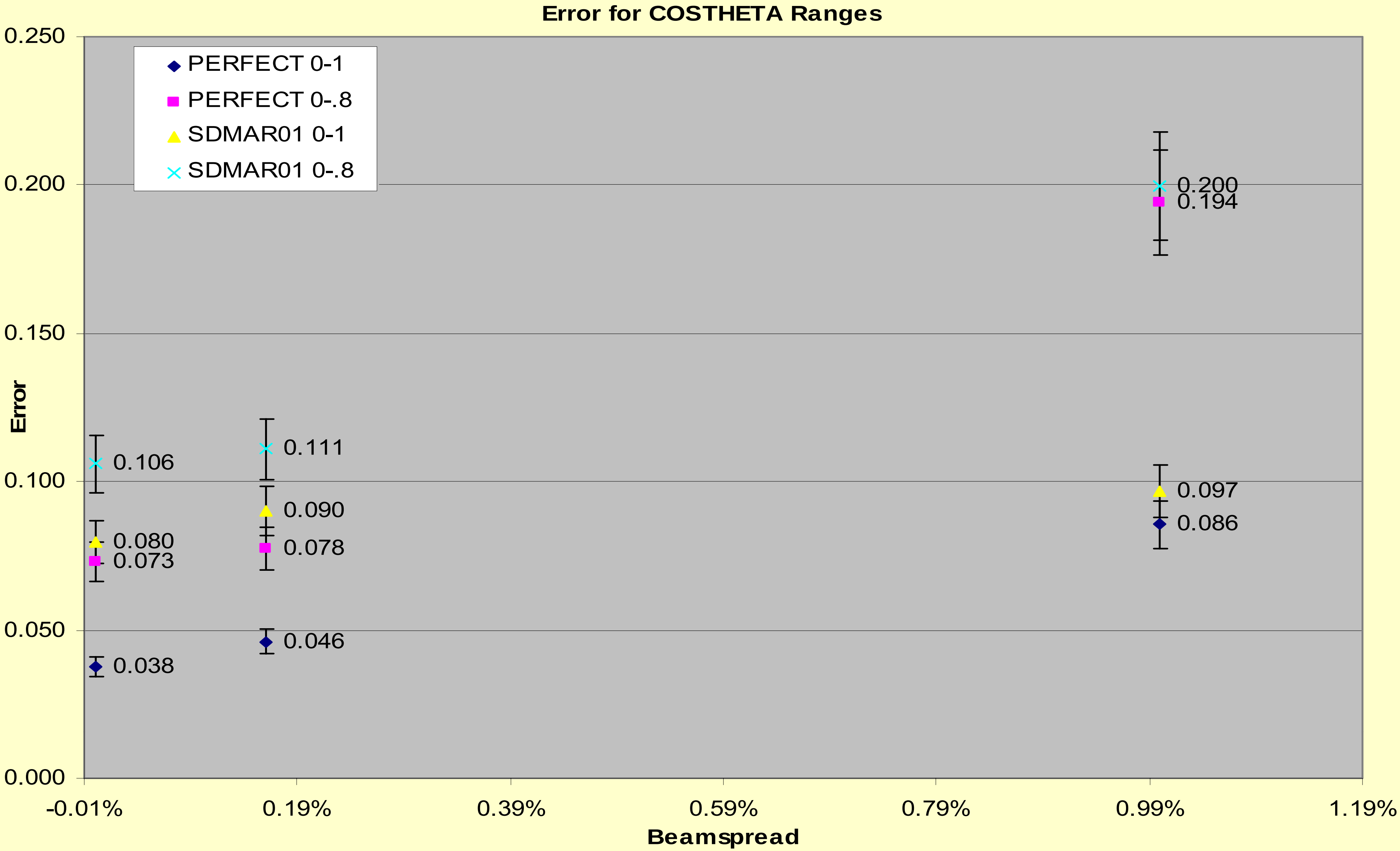


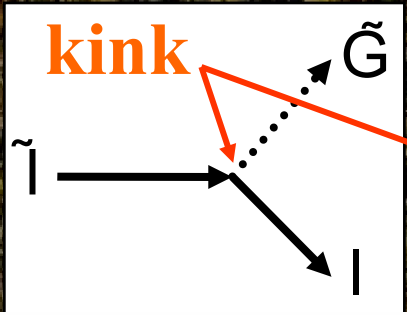
Figure 1: SPS 1 mass spectrum of ISAJET

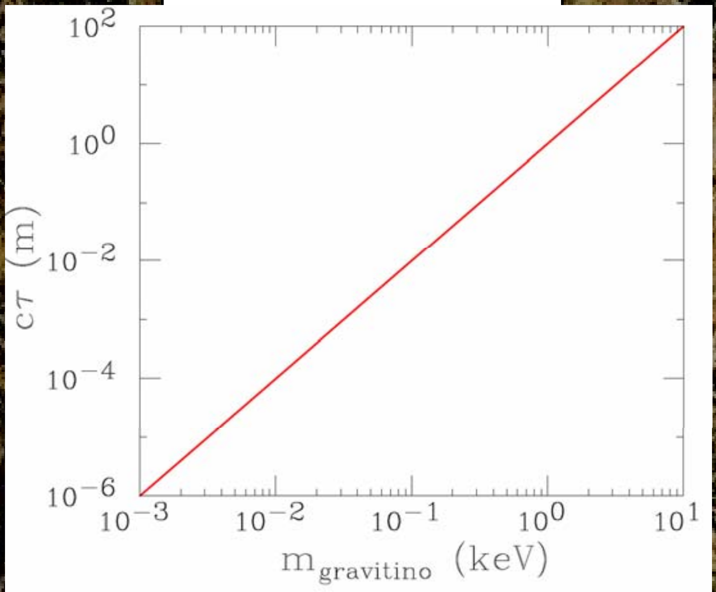
Now, include the full region (|cosθ| < 0.994)

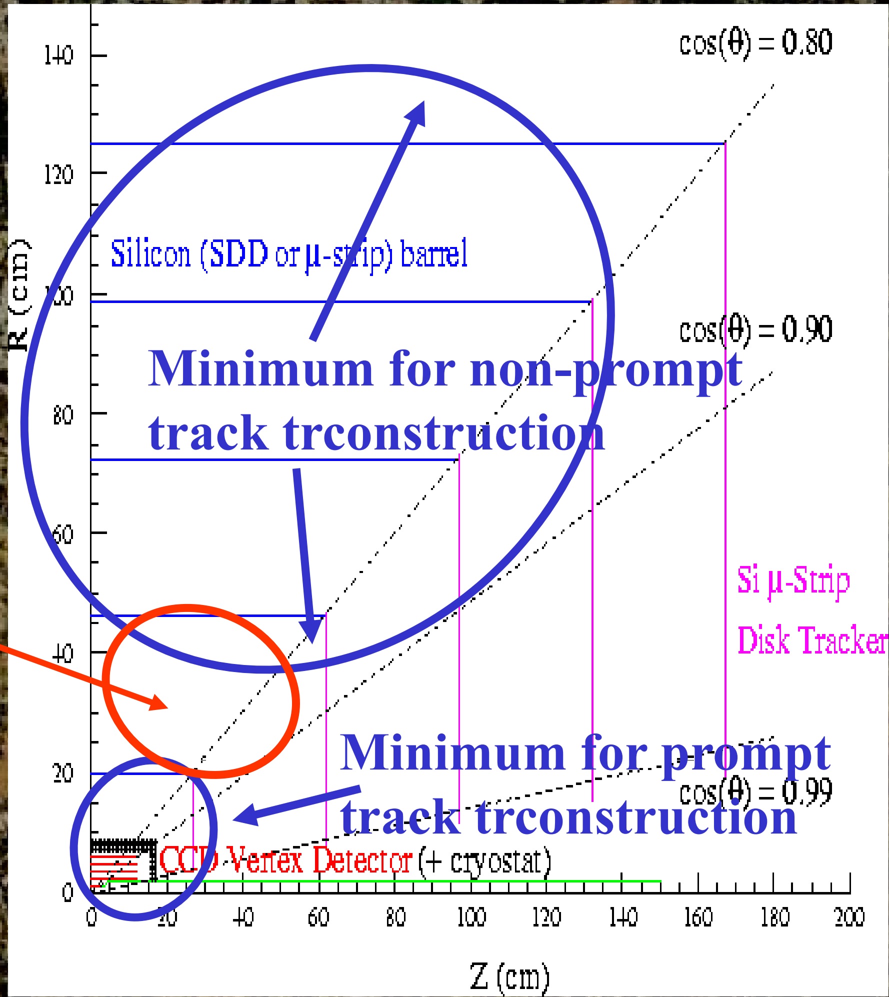


Gauge-Mediated Supersymmetry Breaking

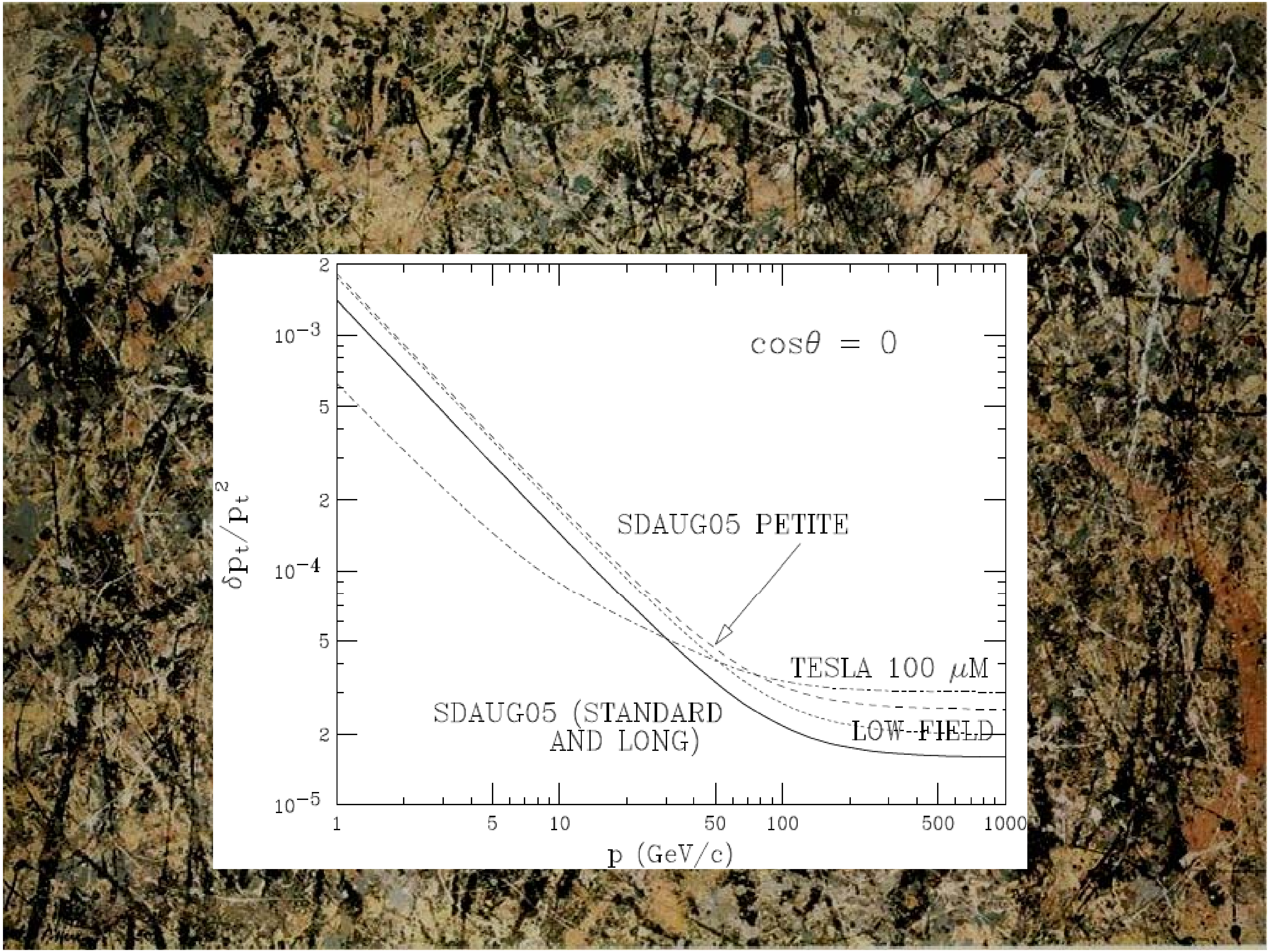
Scenarios with in-flight decay are motivated by cosmological constraints







This will challenge SiD. What about gaseous trackers? (For TPC, non-pointing ⇔ out-of-time)



cosθ = 0
SDAUG05 PETITE
TESLA 100 μM
SDAUG05 (STANDARD
AND LONG)
LOW FIELD
δp_t/p_t^2
p (GeV/c)

SCHUMM'S GUIDE to squeezing blood from stone

1. Discriminate

2. Nurture

3. Produce