Tracking R&D at SCIPP:

Charge Division
Long Ladder Readout Noise
Non-Prompt Tracks with SiD

CERN Linear Collider Workshop
October 18-22 2010

Charge Division

Can a longitudinal coordinate be measured with microstrip sensors?

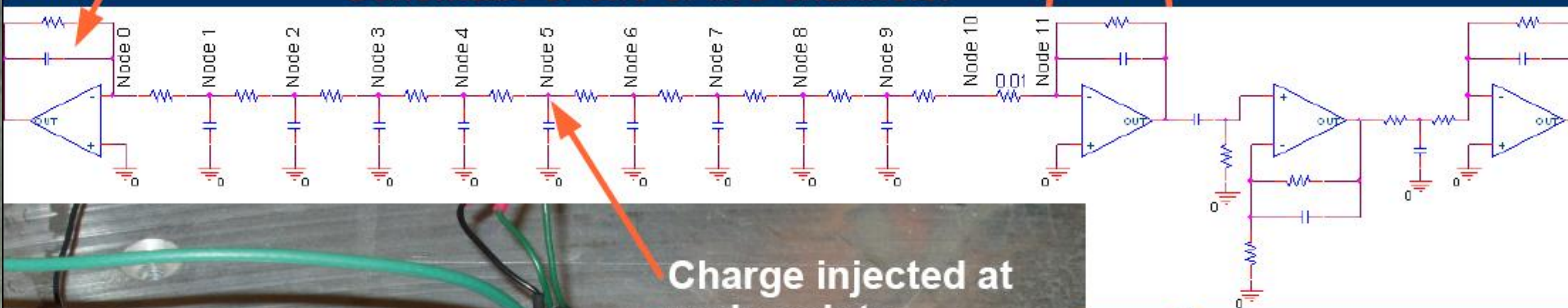
Explore with PC-board microstrip mock-up and PSpice simulation

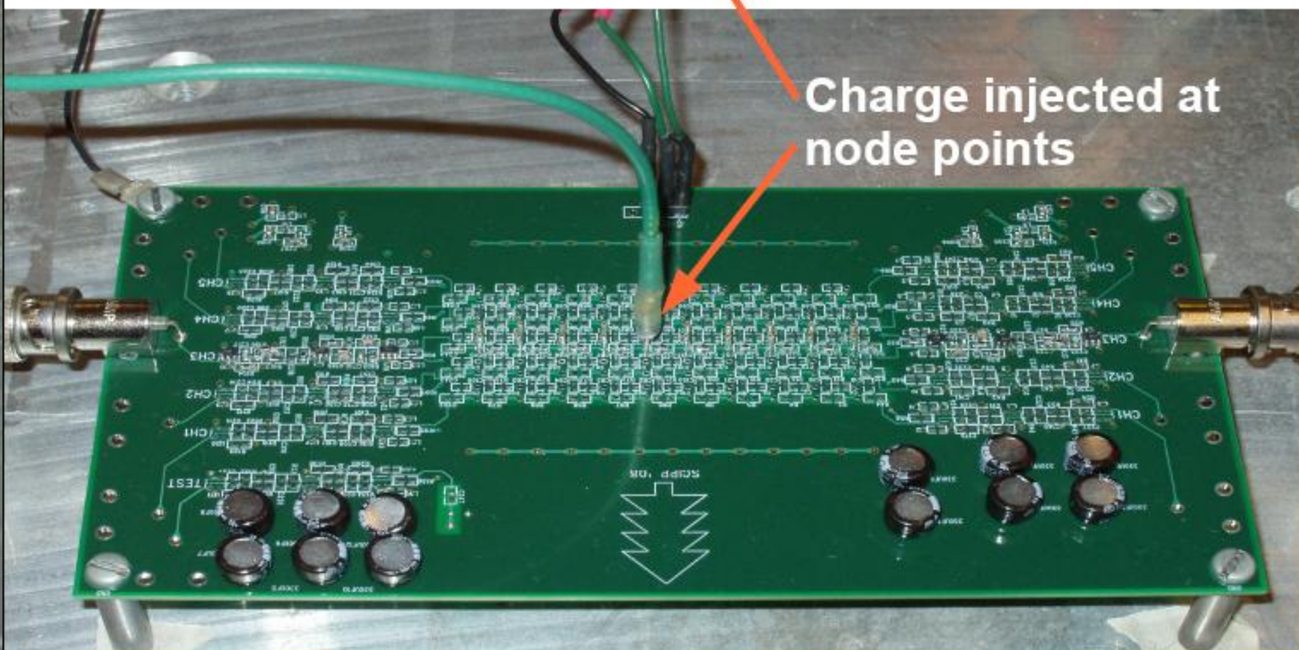
PC Board Model Of A Five Channel Silicon Strip Detector With Charge Division Readout

Left side amplifier design is identical to the right side, but not shown

Preamp is a high GBP charge sensitive integrator.

Schematic of one of five channels.



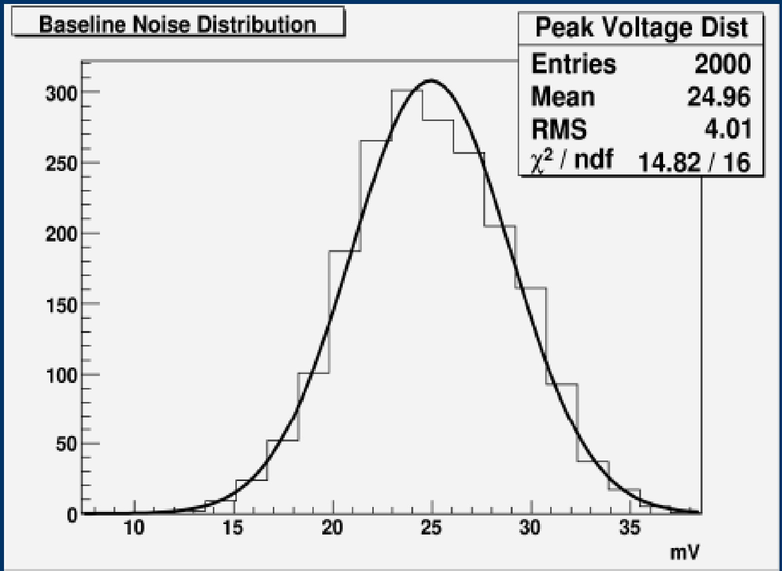


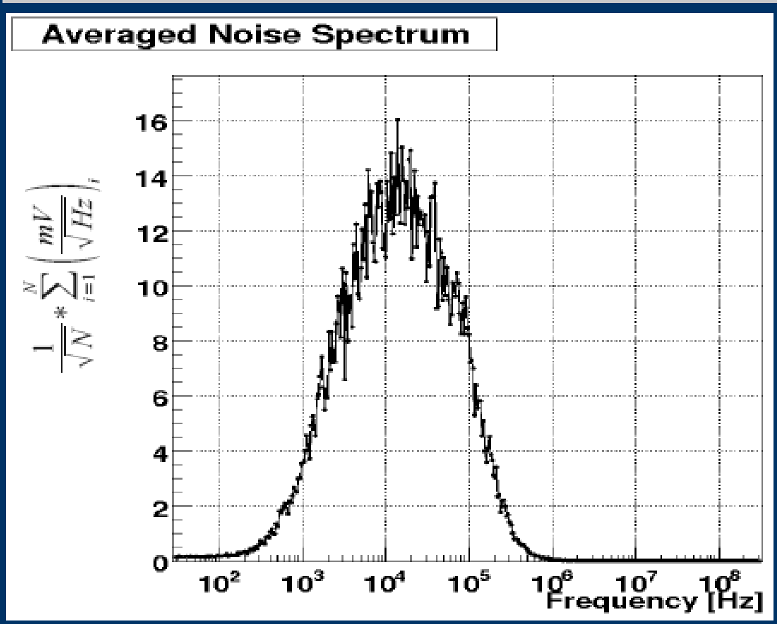
Charge injected at node points

- Three stage integration, with the shaping time of each stage ≈⅓ total shaping time
- AC coupled to preamp via differentiation with long shaping time to minimize undershoot

Benchmarking
Simulation With The PC Board

SCIPP





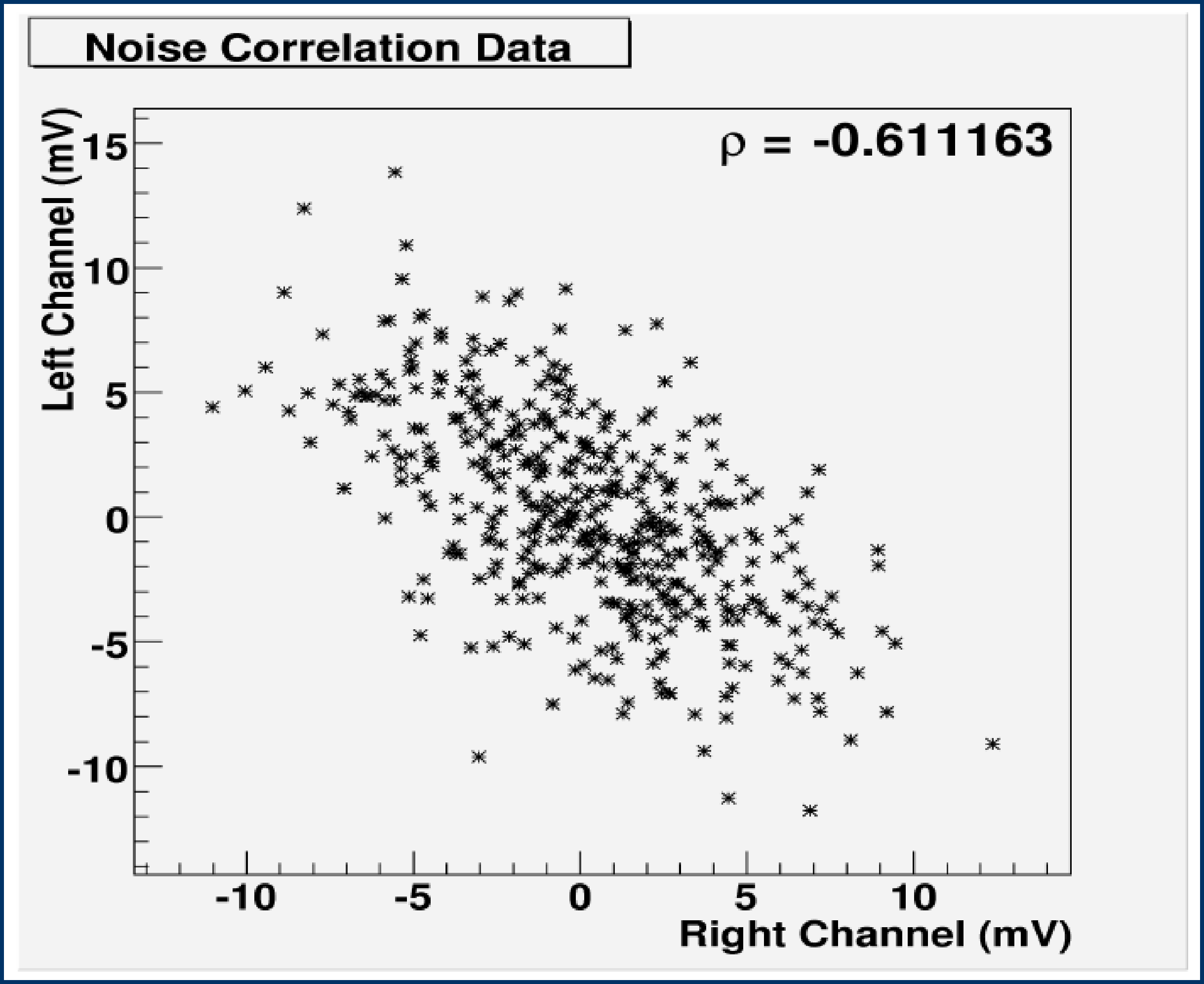
R=600kΩ C=12.7pF

Measurement Method	Noise [mV]	Noise [fC]
Trace Merging	3.67	0.23
Spectrum Analyzer	3.80	0.24
Oscilloscope RMS	4.01	0.25

PSpice Prediction	3.69	0.23

- Noise measurement agrees amazingly well with Pspice prediction!!
- We have confidence in the Pspice model.
- Pspice shows opamp noise contribution is less than 1% confirming that the noise is dominated by the RC network

Calculating Longitudinal Position Resolution



- Measured an anti-correlation in noise between the left and right sides of ρ=-0.61
- Anti-correlation is predicted qualitatively by Radeka for shaping times in the linear regime.

Calculating Longitudinal Position Resolution

$$P=\frac{Q_R}{Q_L+Q_R}=\frac{\alpha}{1+\alpha}= \text{fractional position}$$

$$\alpha=\frac{Q_R}{Q_L}$$

$$\sigma_\alpha=(\alpha)\left\{\left(\frac{\sigma_R}{Q_R}\right)^2+\left(\frac{\sigma_L}{Q_L}\right)^2-2\rho\left(\frac{\sigma_R}{Q_R}\right)\left(\frac{\sigma_L}{Q_L}\right)\right\}^{\frac{1}{2}}$$

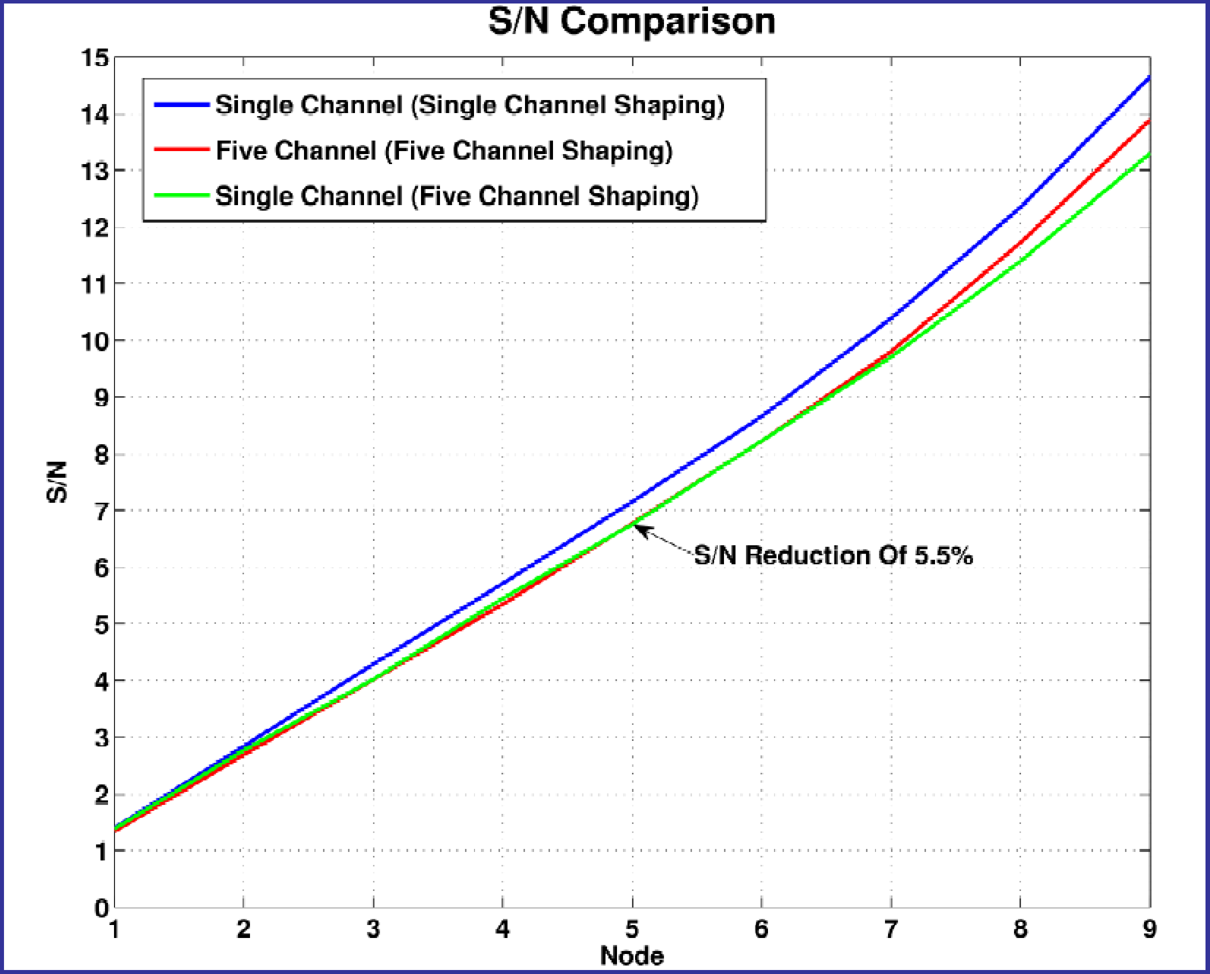
Anti-correlation factors in here

$$\sigma_P=\left|\frac{dP}{d\alpha}\right|\sigma_\alpha=\left(\frac{1}{(1+\alpha)^2}\right)\sigma_\alpha$$

- We measure σ_P to be **≈6.1mm** for a 10cm, 600kΩ, 12.7pF silicon strip detector
- Radeka predicts σ_P to be ≈6.5mm for a 10cm, 600kΩ, 12.7pF silicon strip detector.
- Asymmetry in σ_P due to slight non-linearity in 2.5T shaping time choice as well as measurement uncertainty.

	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9
Q_R [fC]	0.32	0.64	0.95	1.28	1.60	1.95	2.33	2.77	3.23
Q_L [fC]	3.24	2.75	2.33	1.94	1.60	1.26	0.94	0.65	0.32
P	0.090	0.189	0.290	0.400	0.500	0.607	0.713	0.810	0.910
$\sigma_R=\sigma_L$ [fC]	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
σ_P	**0.0598**	**0.0609**	**0.0615**	**0.0616**	**0.0617**	**0.0618**	**0.0617**	**0.0603**	**0.0600**

Final step: practical detectors are not isolated strips. Include two nearest-neighbors in simulation:



Network effects lead to ~5% reduction in longitudinal resolution.

Long-Ladder Readout Noise

Probe conventional notions about dependence of readout noise on distributed capacitance and series resistance

Standard Form for Readout Noise (Spieler)

Series Resistance

Parallel Resistance

$$Q^2 = F_i \tau \left(2eI_d + \frac{4kT}{R_B} + {i_{na}}^2 \right) + \frac{F_v C^2}{\tau} \left(4kTR_s + {e_{na}}^2 \right) + 4F_v A_f C^2$$

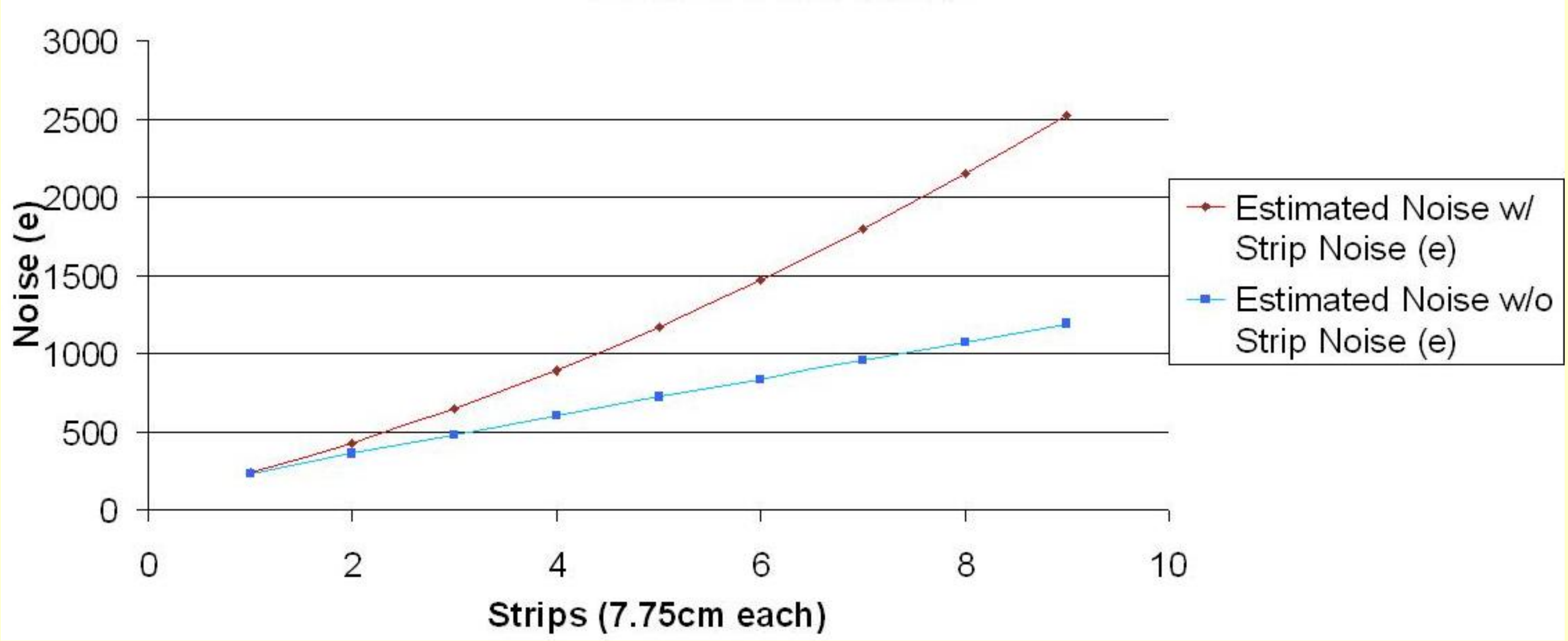
Amplifier Noise (parallel)

Amplifier Noise (series)

Dominant term for long ladders (grows as $L^{3/2}$)

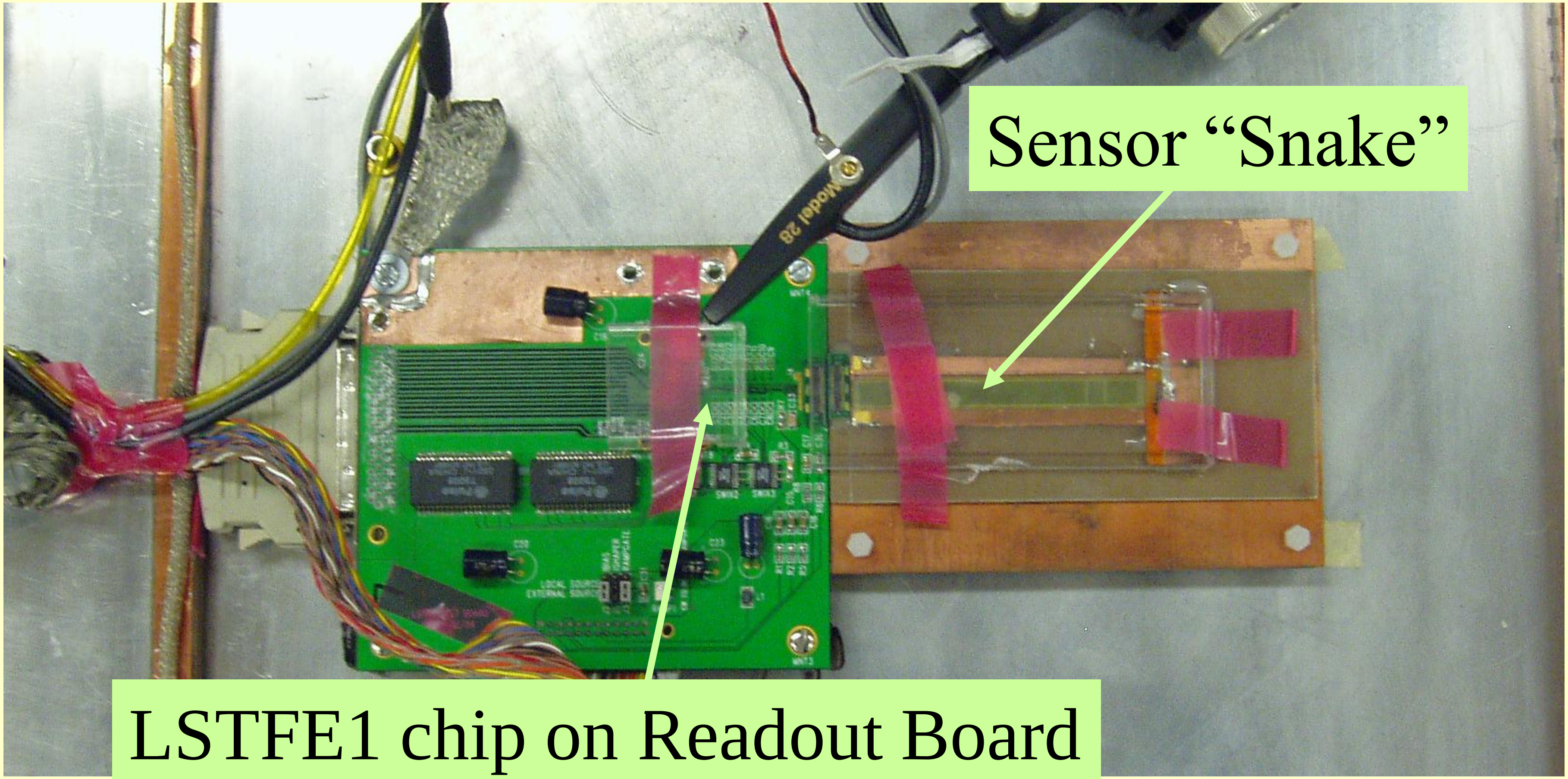
F_i , F_v are signal shape parameters that can be determined from average scope traces.

Expected Noise vs. Ladder Length



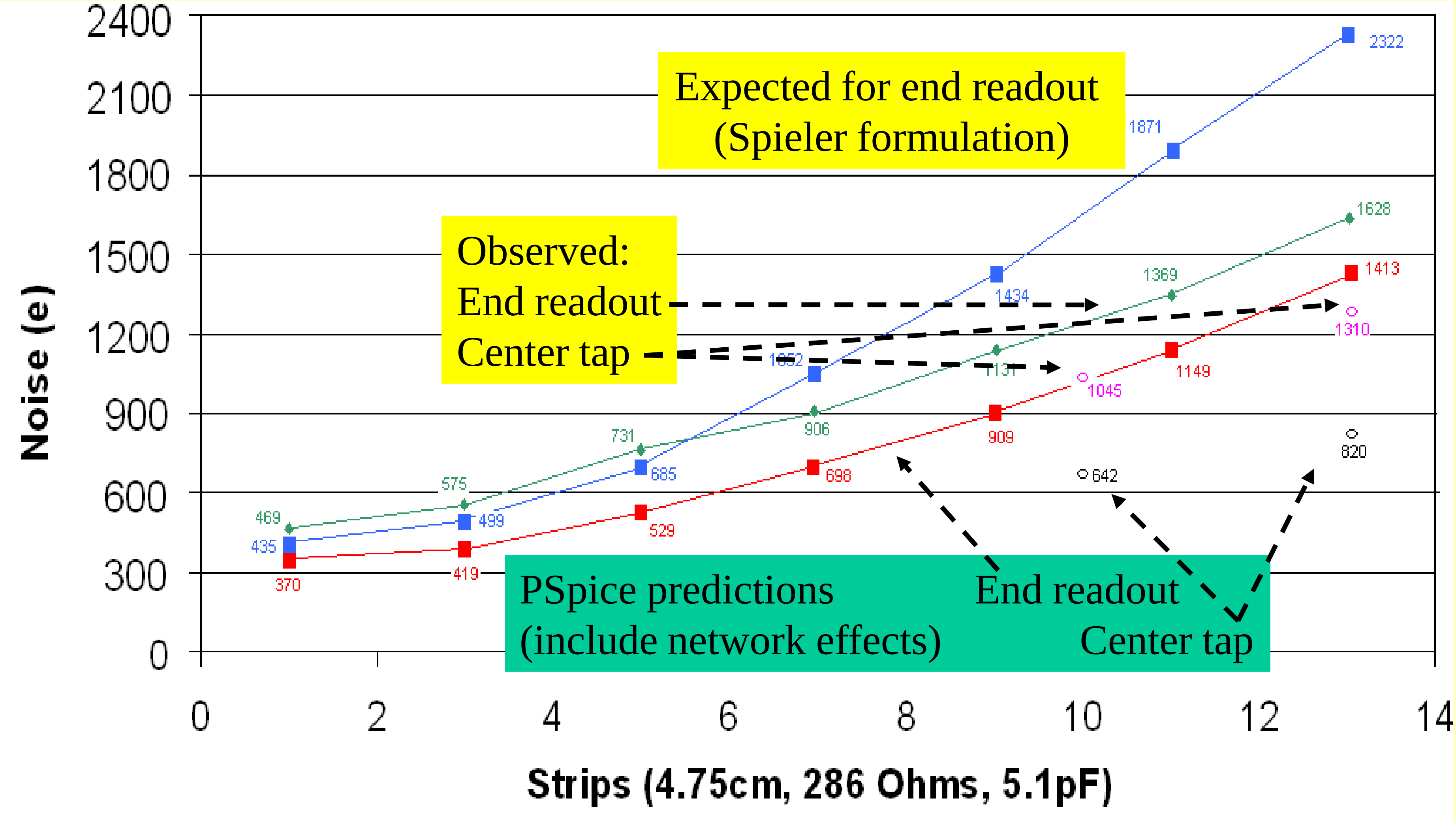
Series noise expected to dominate for narrow (50 μm) pitch sensors above ~25 cm long

Sensor "Snake": Read out up to 13 daisy-chained 5cm sensors (with LSTFE-1 ASIC)



Can read out from end, or from middle of chain ("center-tap")

Comparison of Results and Expectations



PSpice simulation is "first pass" (crude amplifier model; parasitic effects not yet incorporated, etc.)

Non-Prompt Tracking with the SiD

Explore performance via explicit signature: Metastable stau NLSP (Gauge-Mediated SUSY)

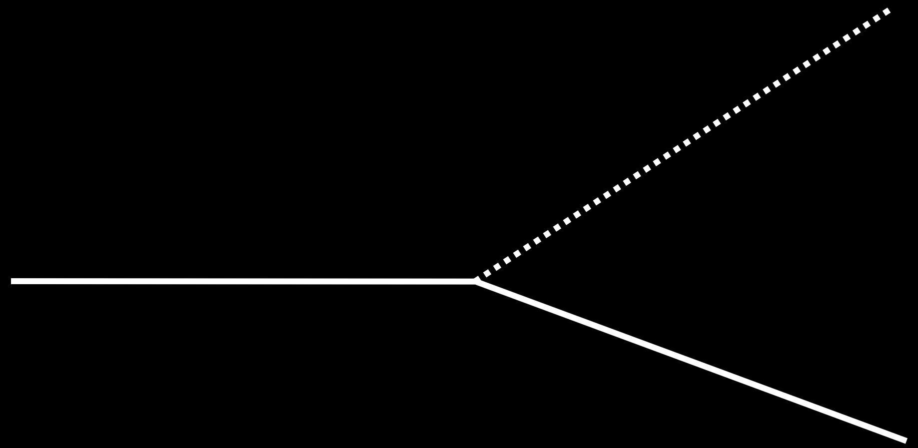
Reconstructing Metastable Staus w/ SiD

Gauge-Mediated SUSY

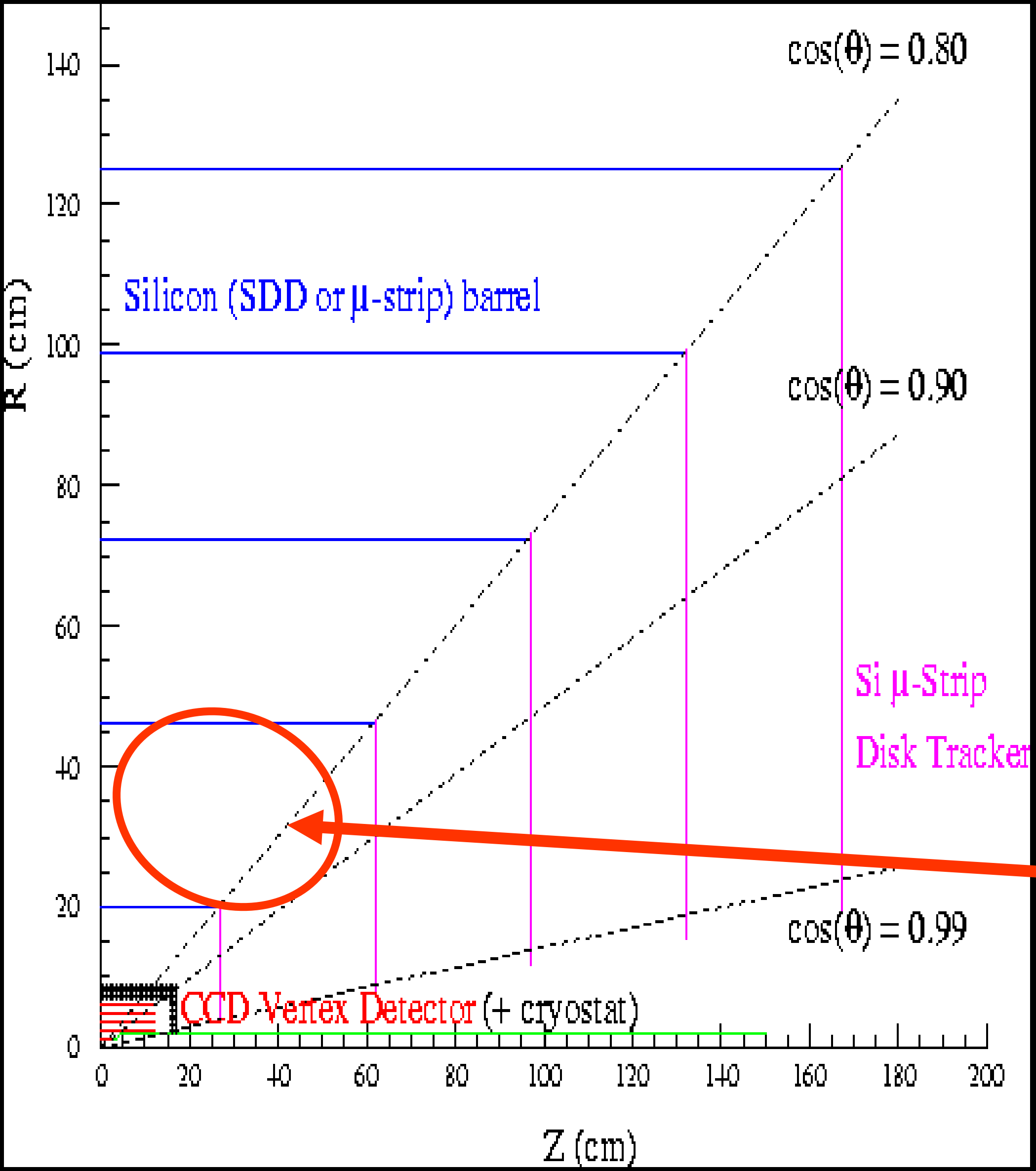
- Large tract of parameters space as stau NLSP
- Metastable ($\gamma\beta c\tau_{stau}$ ~ centimeters) is in cosmologically preferred region

Process is

with



Reconstructing Metastable Staus w/ SiD



Start with:

5+1 layers for inside track

4 layers for outside track

➔ Restricted range in r_{decay} for now; will expand soon

Measuring Staus with the SID

Stau sample:

11.1 fb^{-1} of $e^+e^- \rightarrow$ stau pairs with

- m_{stau} = 75 GeV
- E_{cm} = 500; $\sigma_{\tau\tau}$ = 90 fb
- $\beta\gamma c\tau$ = 23 cm

Background sample:

5.3 fb^{-1} combined SM background

Reconstructing Metastable Staus w/ SiD

Focus initially on r_{decay} = 22-47 cm…

Reconstruct decays by requiring:

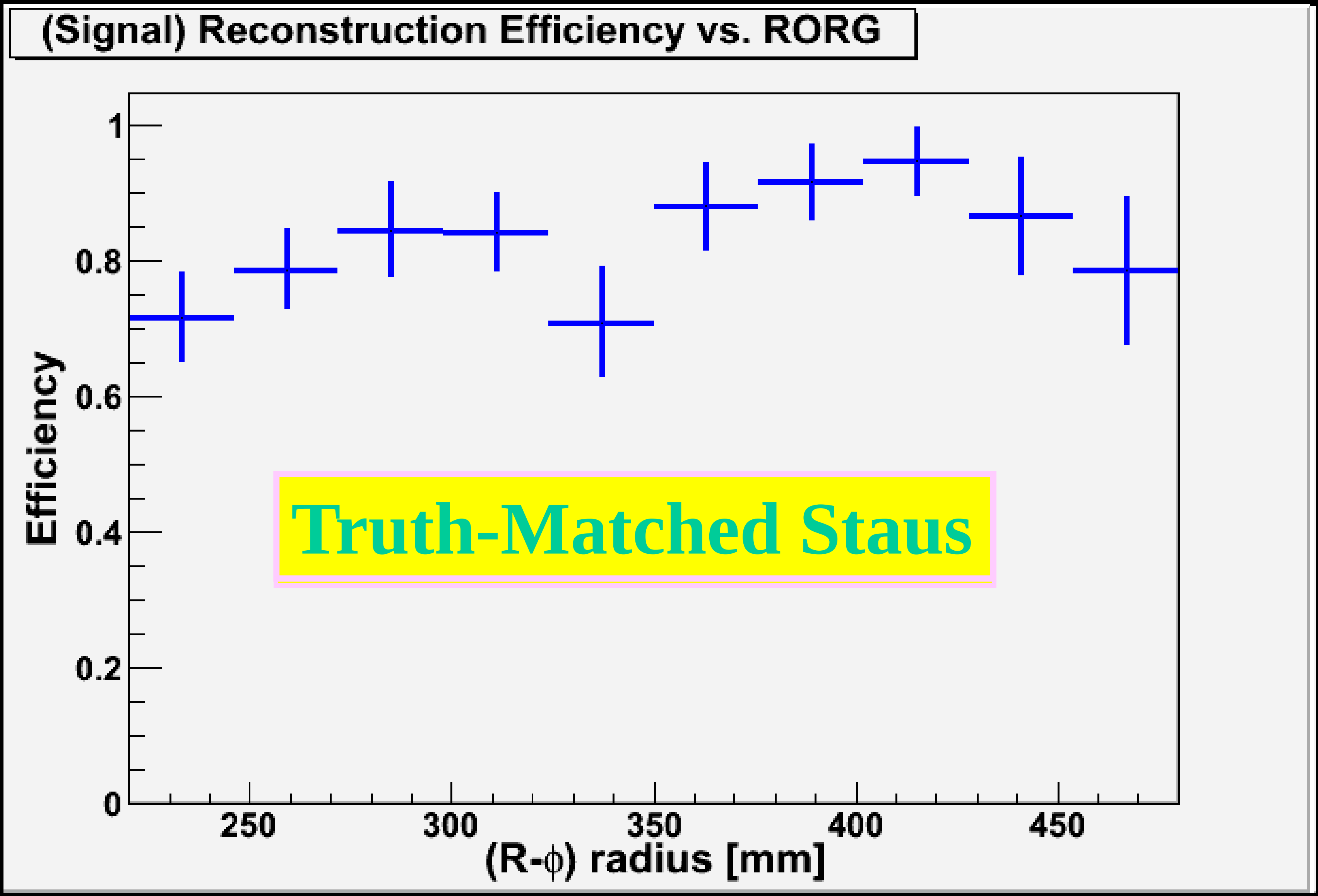
- Outer hit of primary track on first tracker layer
- Inner hit of non-prompt track on second tracking layer
- Both tracks be on the same side of the Barrel (in z)
- The sign of the track curvatures match

- Non-prompt track curvature larger than the primary

- Tracks have a geometric intersection in the x-y plane

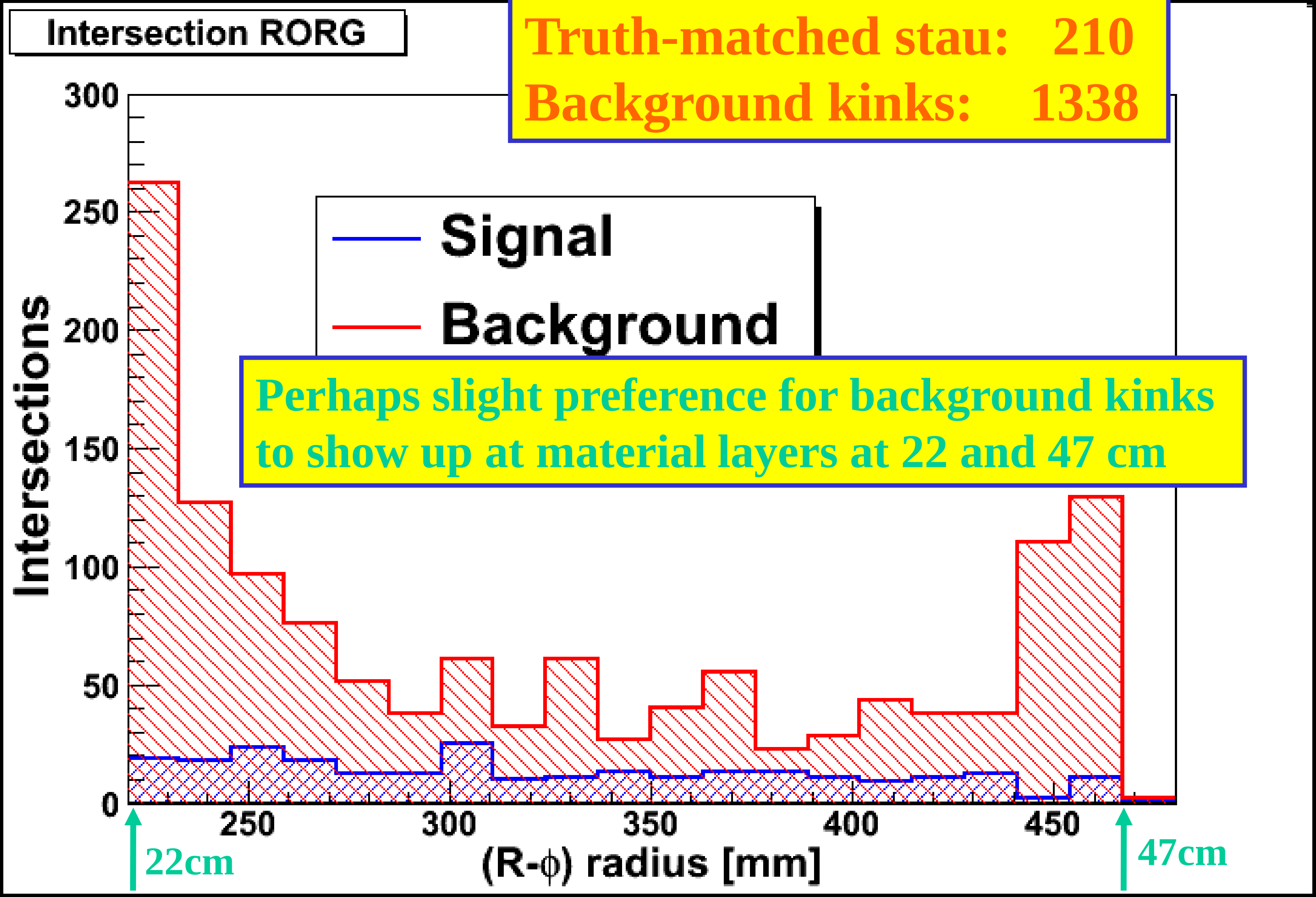
Of 294 staus with 22<r... <27 and |cosθ| < 0.5, 239

Stau Reconstruction Efficiency



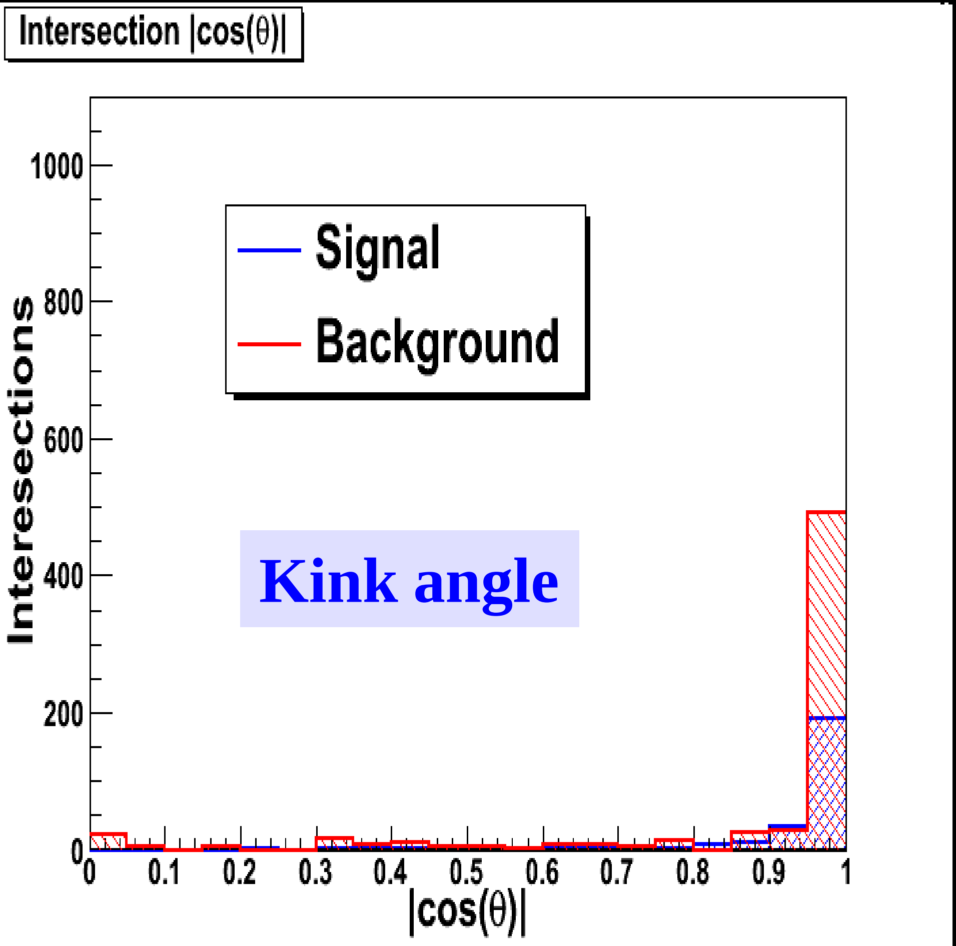
Signal to Background for 10 fb^{-1}

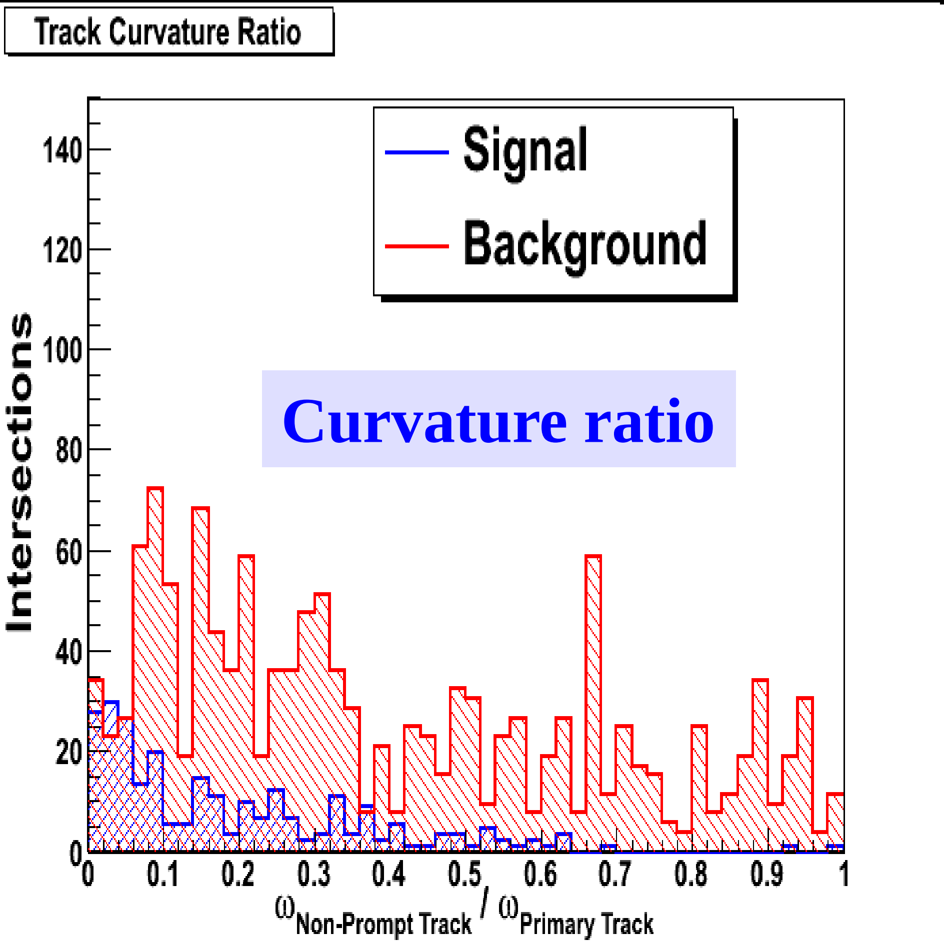
Truth-matched stau: 210
Background kinks: 1338



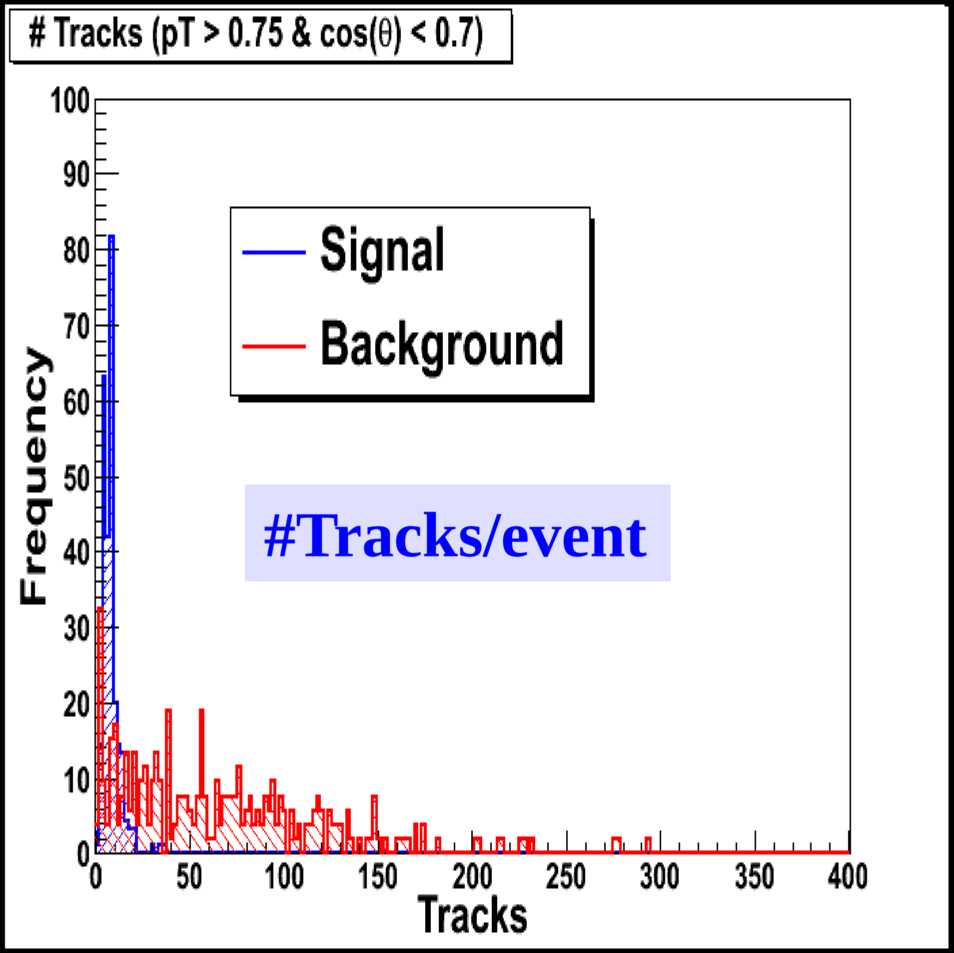
Perhaps slight preference for background kinks to show up at material layers at 22 and 47 cm

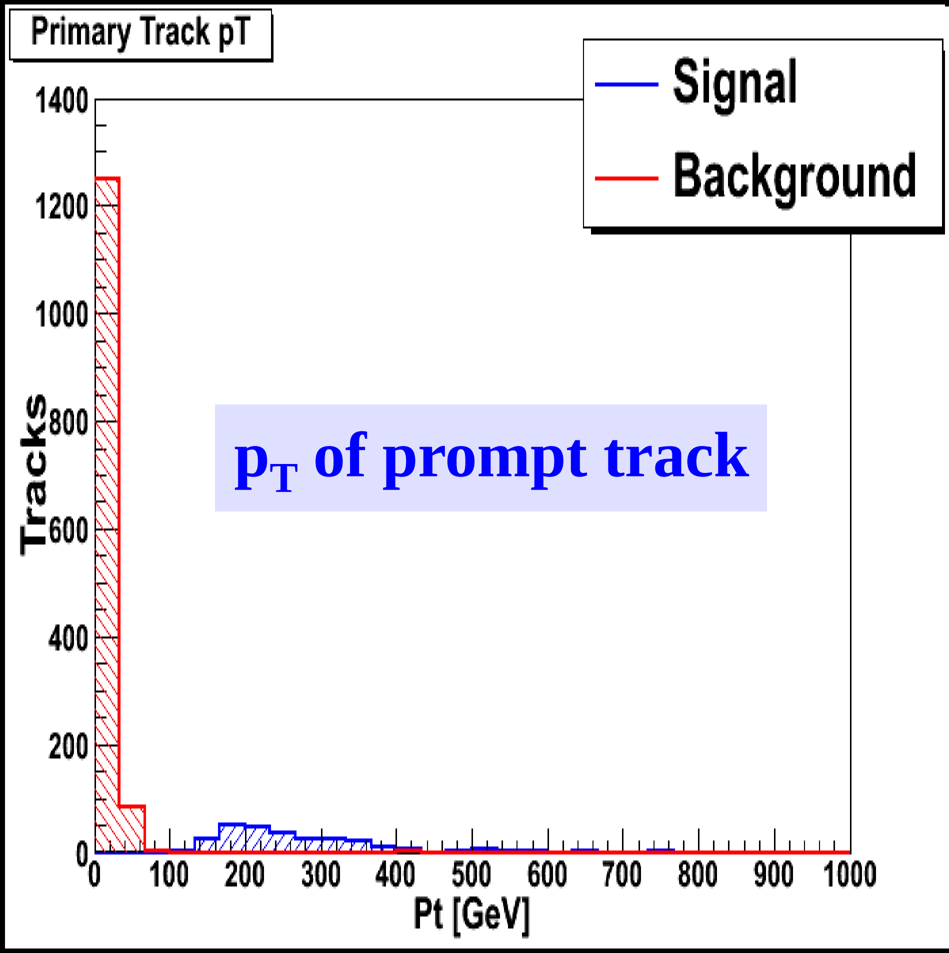
Signal to Background (10 fb^{-1})





Signal to Background (10 fb^{-1})





Good separation between signal and background for #tracks/event and track p_t

Wrap-Up

Charge Division:

Longitudinal resolution of σ_z=6mm seems achievable for a 10cm-long sensor.

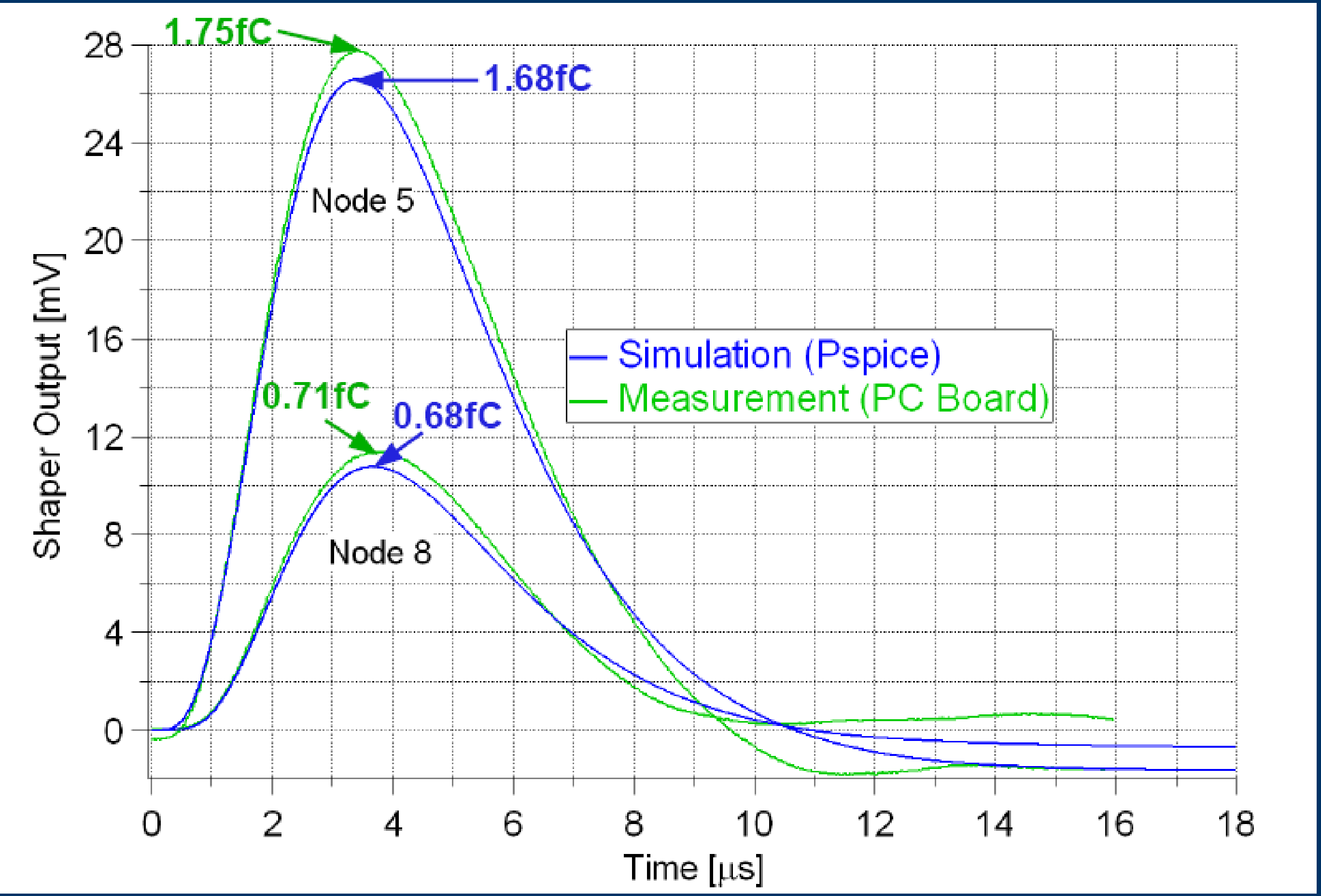
Long Ladder Readout Noise:

Simulation and data show significantly less readout noise for long ladders than expected. “Center-tapping” yields even further reductions.

Non-Prompt Tracks with SiD:

Reconstructing clean metastable stau signature between first and second tracking layer seems quite plausible. Beginning to look in different radial regions.

Benchmarking Simulation With The PC Board



Comparison of shaper output between simulation and measurement for 600kΩ, 12.7pF, 2.5T shaping time.

- Target rise time is <u>1.83μs (2.5T)</u> from 1%→peak.
- Can see additional rise time added by diffusive line RC network which motivates the rise time method.
- Rise times differ by ≈ 5%.
- Peak charge values differ by ≈ 4%.
- e^{-1} fall times differ by ≈2.5%.