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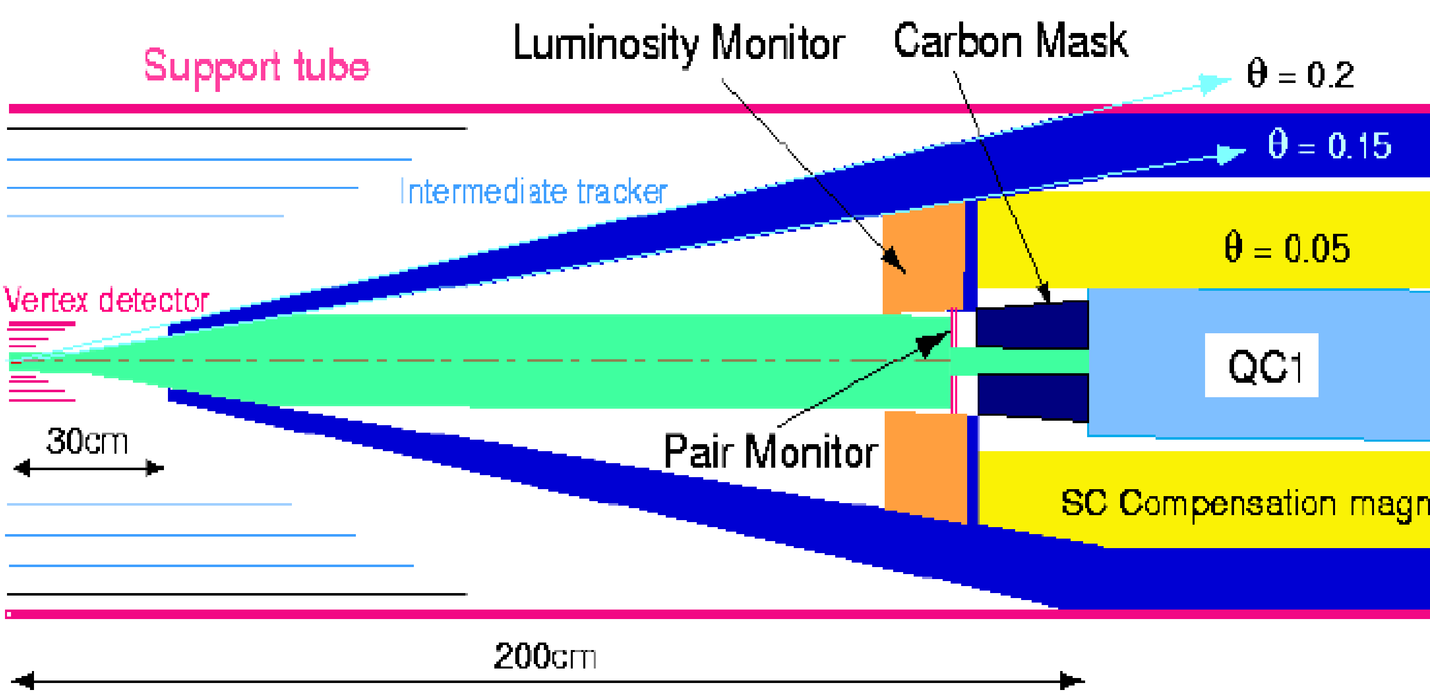
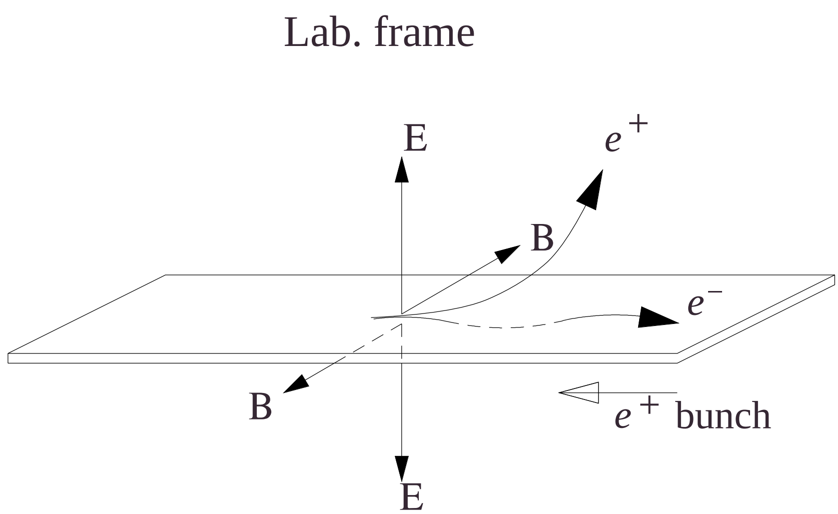
LCWS2000, Fermilab, Oct 26

Pair Monitor for LCs

- Large number of pairs/bunch created by QED process $\gamma\gamma \rightarrow e^+e^-$
- Same sign particle acquire Pt kick by EM field of on-coming bunch
- P_t and Φ distribution of deflected e^+ (e^-) can be used to measure σ_x and σ_y of on-coming bunches

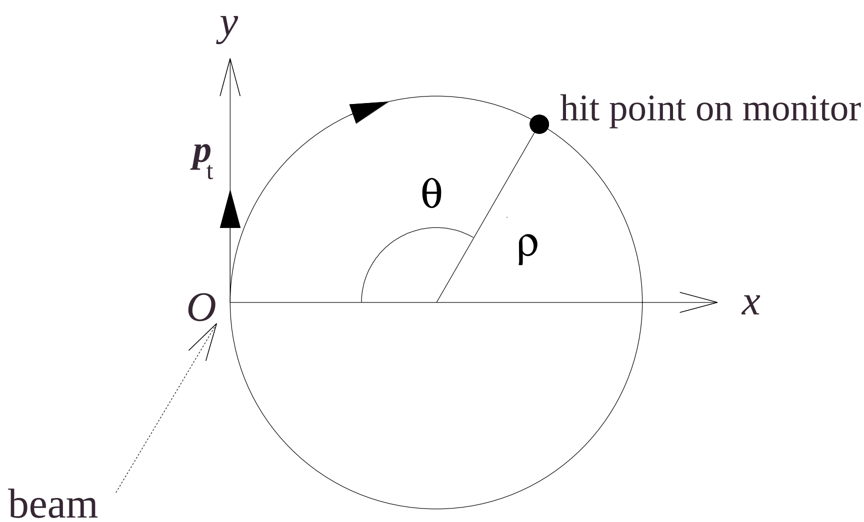


Kinematic Configuration of Pair 'Background'



- $|E| = |B|$
  $\rightarrow$ no force from the co-moving bunch.
- $E(dyne/esu) = B(gauss) \sim 4 \times 10^7$
  $\rightarrow r \sim 170\mu$m for $p = 300$ MeV/c.
  ($\sigma_z \sim 80\mu$m)
- For an incoming e^+ bunch,
  e^- oscillates around the beam plane.
  e^+ acquires a large p_t kick (vertical).
- Round beam $\rightarrow$ no ϕ dependence,
  ϕ dependence $\rightarrow \sigma_y/\sigma_x$ ratio.

Hit Location on the Pair Monitor



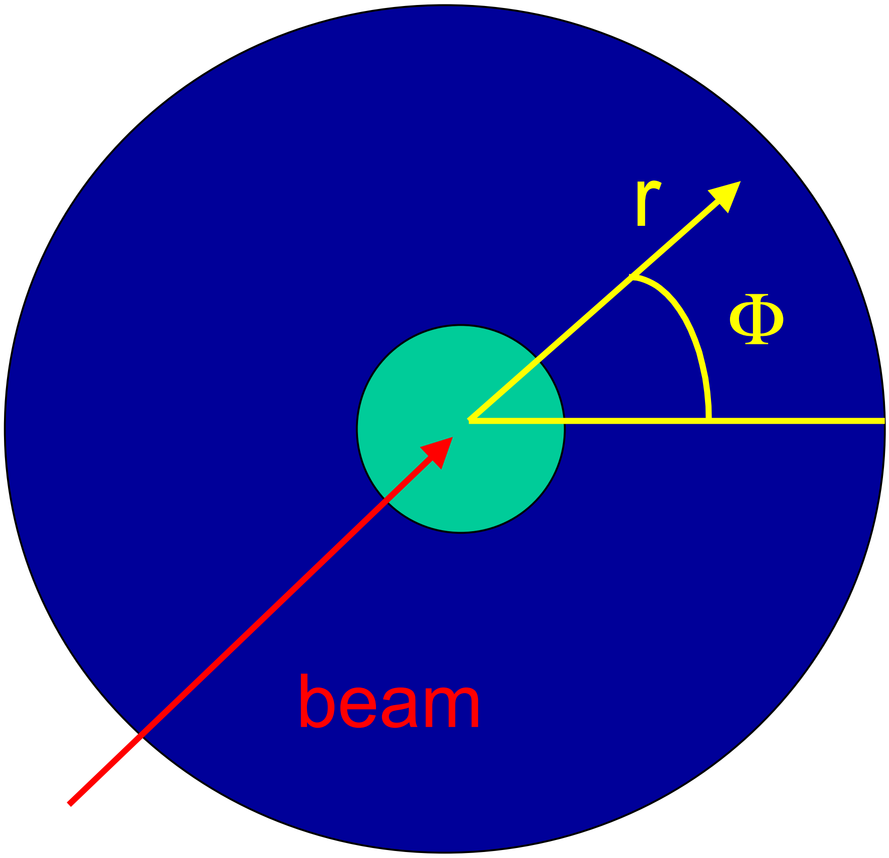
$$\rho(\mathrm{cm}) = \frac{p_t(\mathrm{MeV}/c)}{3B_0(\mathrm{Tesla})}, \quad \theta = \frac{3B_0(\mathrm{Tesla})L(\mathrm{cm})}{p_z(\mathrm{MeV}/c)}$$

L : distance to IP

- ρ measures p_t and θ measures p_z.
- For $\sqrt{s} = 500$ GeV, $N_{\mathrm{bunch}} \sim 10^{10}$ and $\sigma_{x/y/z} = 260\mathrm{nm}/3\mathrm{nm}/80\mu\mathrm{m}$,

$$p_{t\mathrm{max}} \sim 20\mathrm{MeV}/c \;\rightarrow\; \rho = 3.3\mathrm{cm}\ (2\mathrm{Tesla})$$

- For $L = 176$ cm, $p_z \sim 350$ MeV$/c \rightarrow \theta \sim \pi$.
- Look at ϕ distribution for $r = 5 \sim 7$ cm.

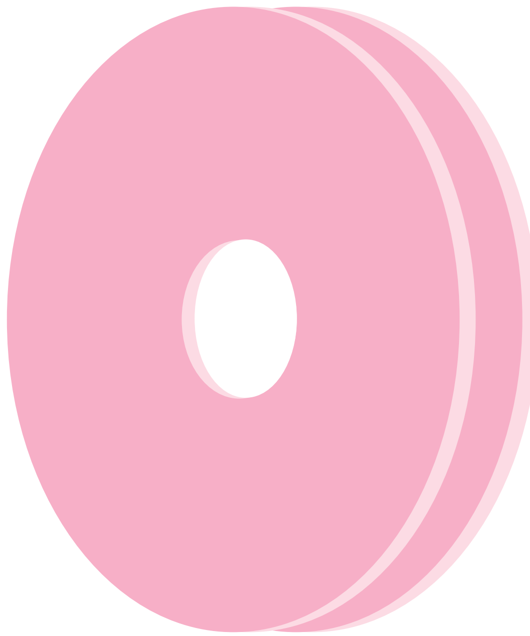


$r \cong p_t \cong (N, (\ln\sigma_x)^{-1}, \sigma_y)$

Azimuthal angle $\Phi \cong (\sigma_x/\sigma_y)$

Pair Monitor

as a beam profile monitor



single Active Pixel Sensor

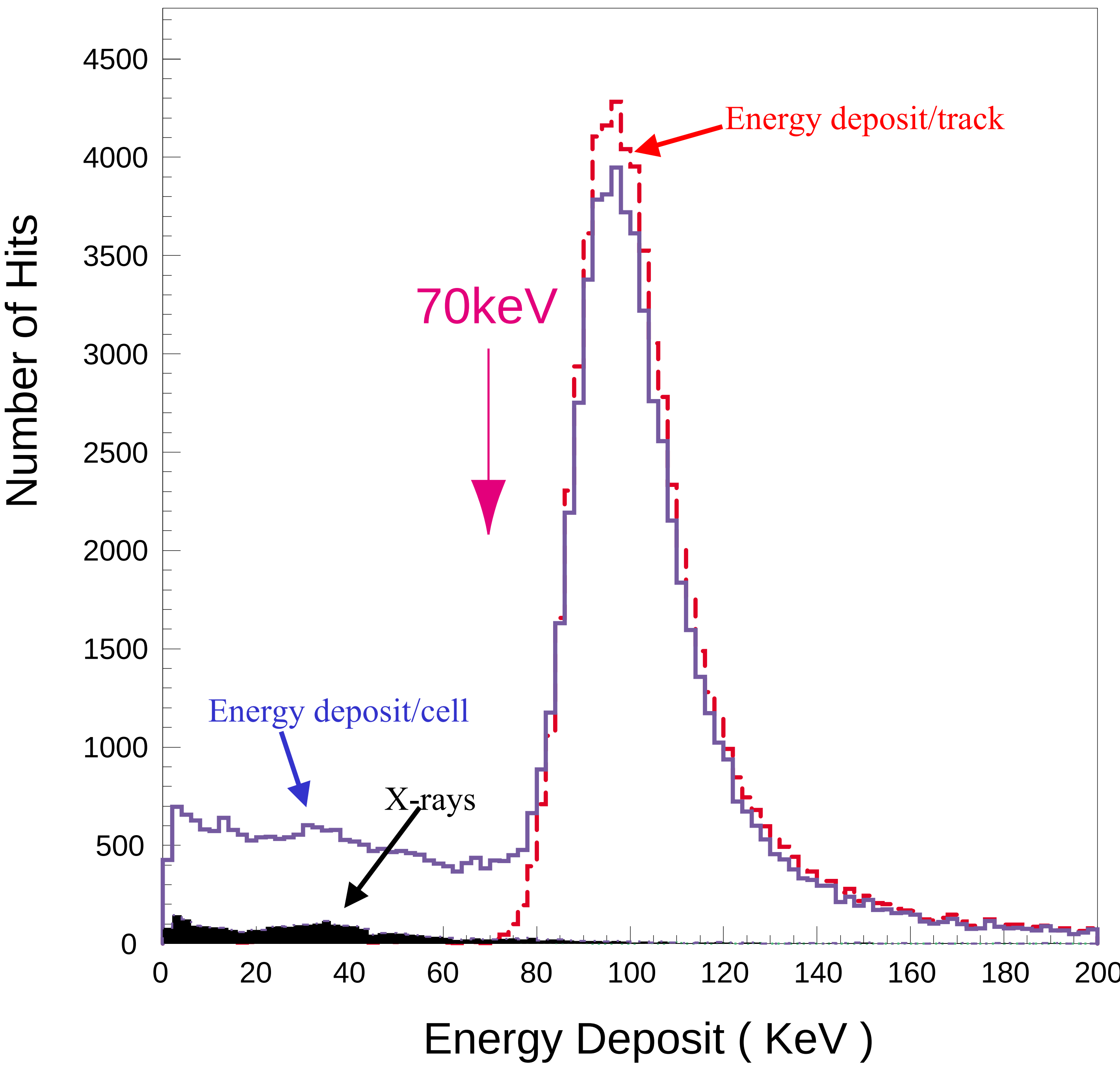
~~double~~ layer of silicon disks

pixel size	100 x 100 μm^2
thickness	300 μm
inner radius	2 cm
outer radius	8.5 cm
location (z)	176 and ~~177~~ cm from IP

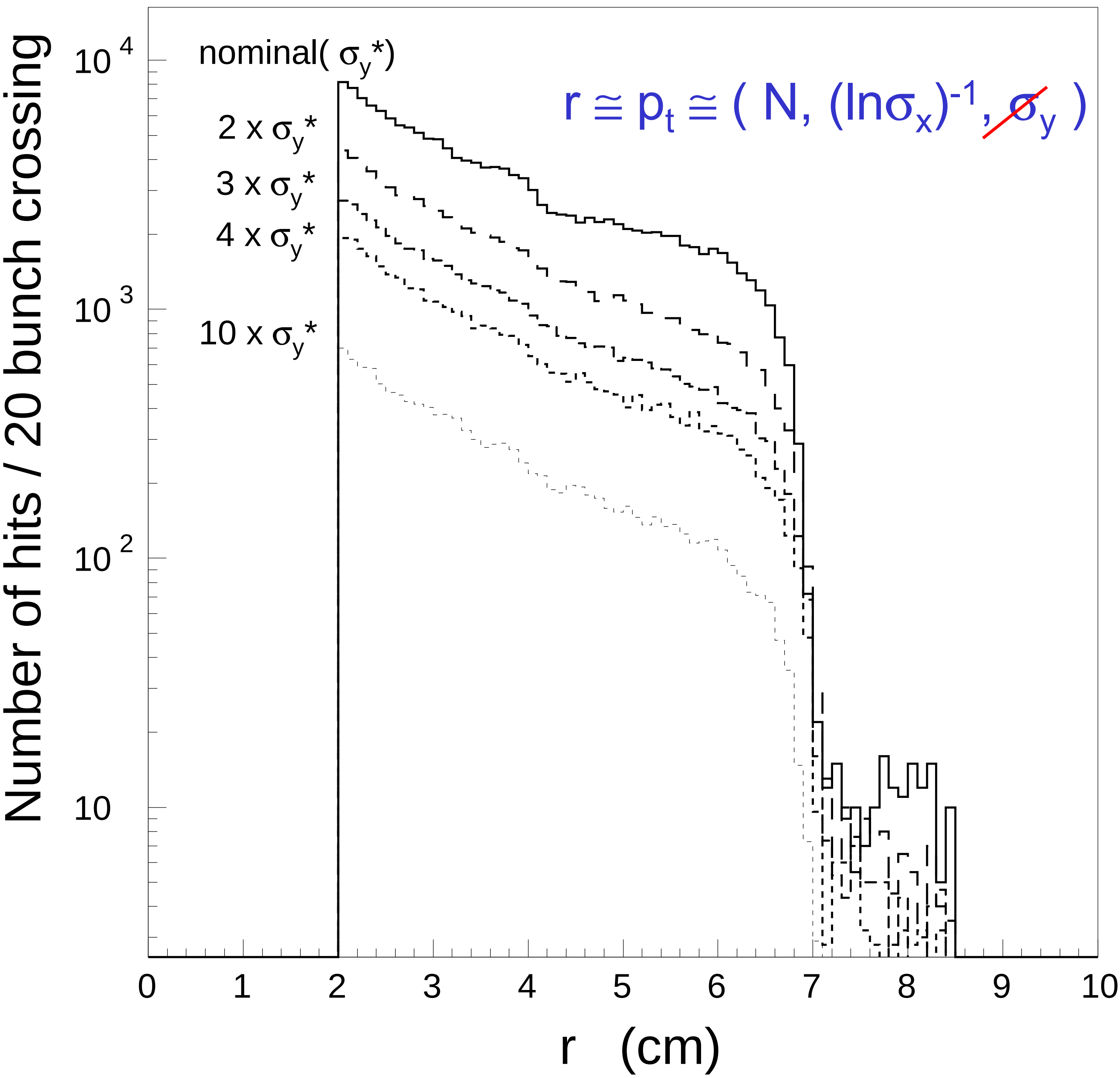
Measurement:

position and energy deposit

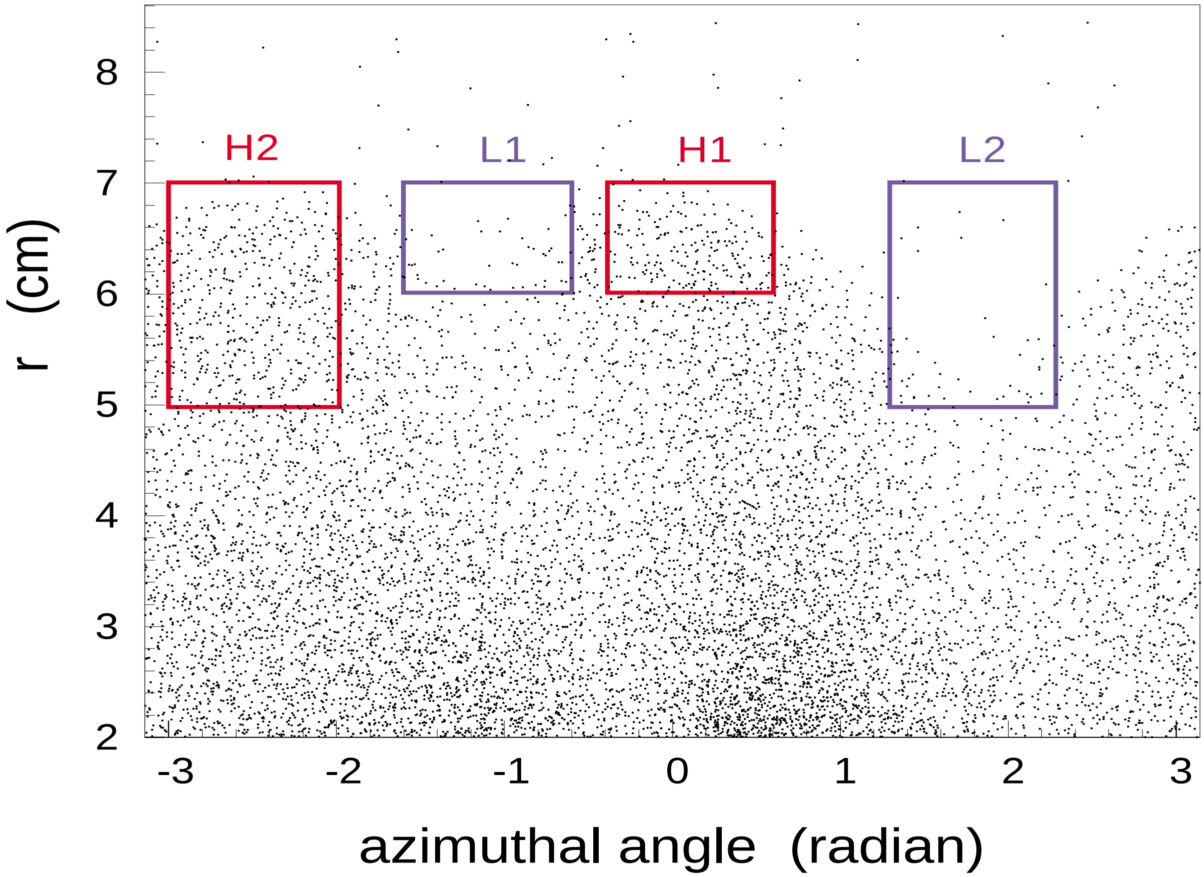
Pair Monitor

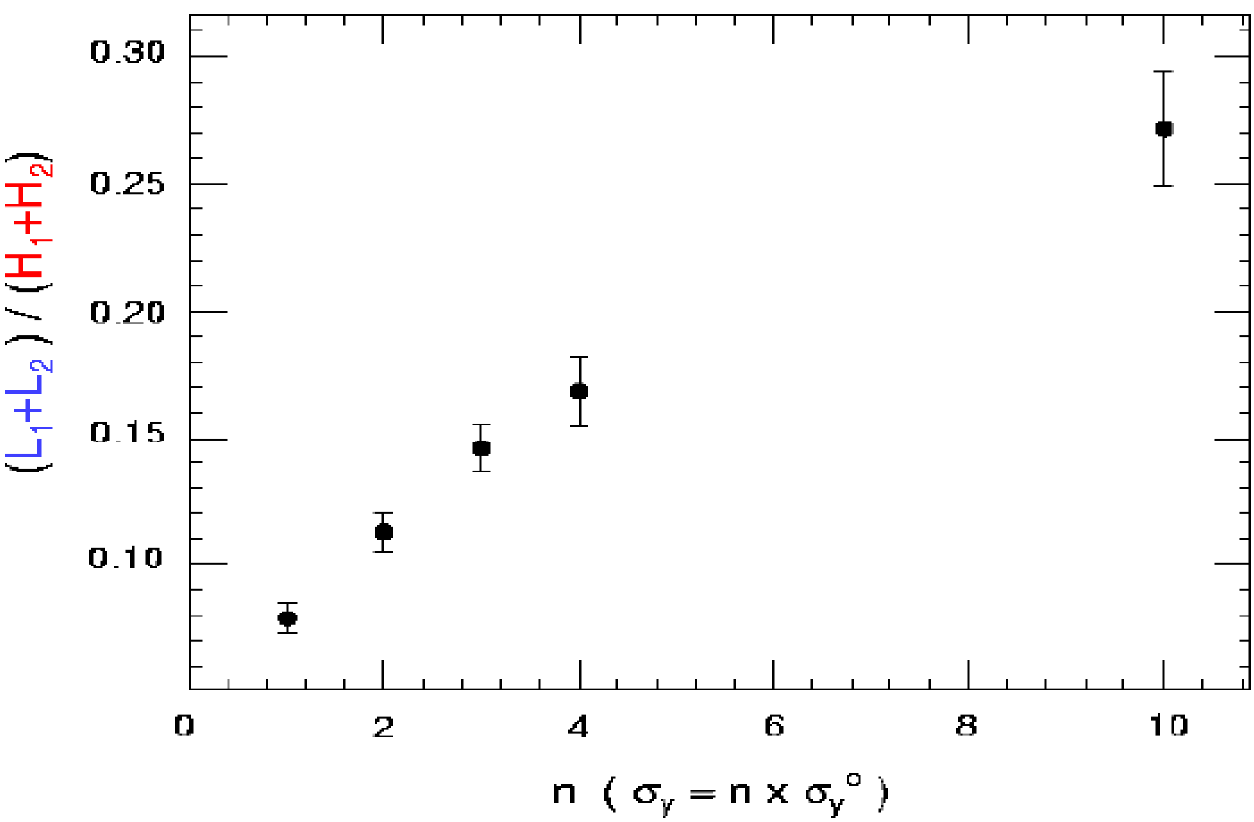


Pair Monitor



Pair Monitor





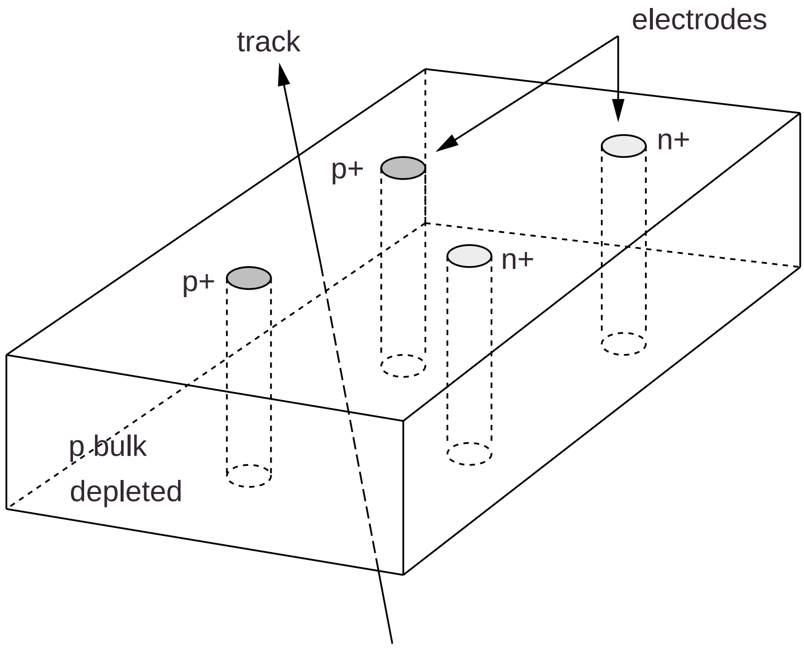
Requirements for the Pair Monitor

- Detect a few 100 MeV electrons.
- 30 hits/mm^2/train for $r = 5 \sim 7$ cm.
- $\sim$ 50 kRad/year.
- $\sim$ 70 keV threshold to reject X-rays.
- Identification of bunch in a train.
- Cover a circular area.

- Rate too high for a Si strip detector.
- CCD does not have TDC for each pixel.
- $\rightarrow$ active pixel sensor.

Use $100 \times 100 \mu\text{m}^2$ pixel.
TDC on each pixel.
Gating to reduce occupancy and/or
Multi hit TDC capability.

3D Pixel Sensor

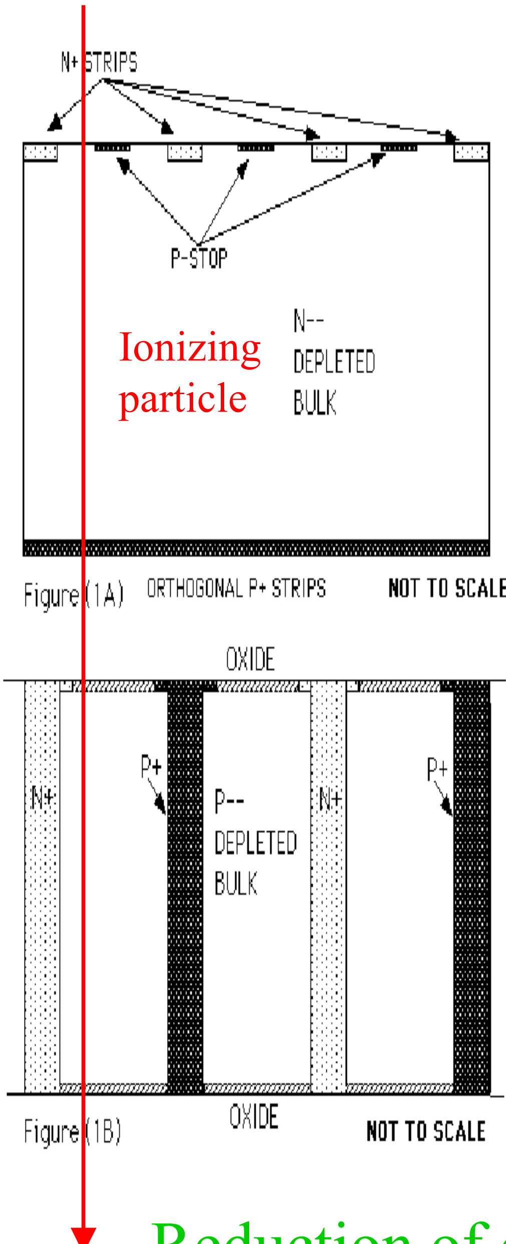


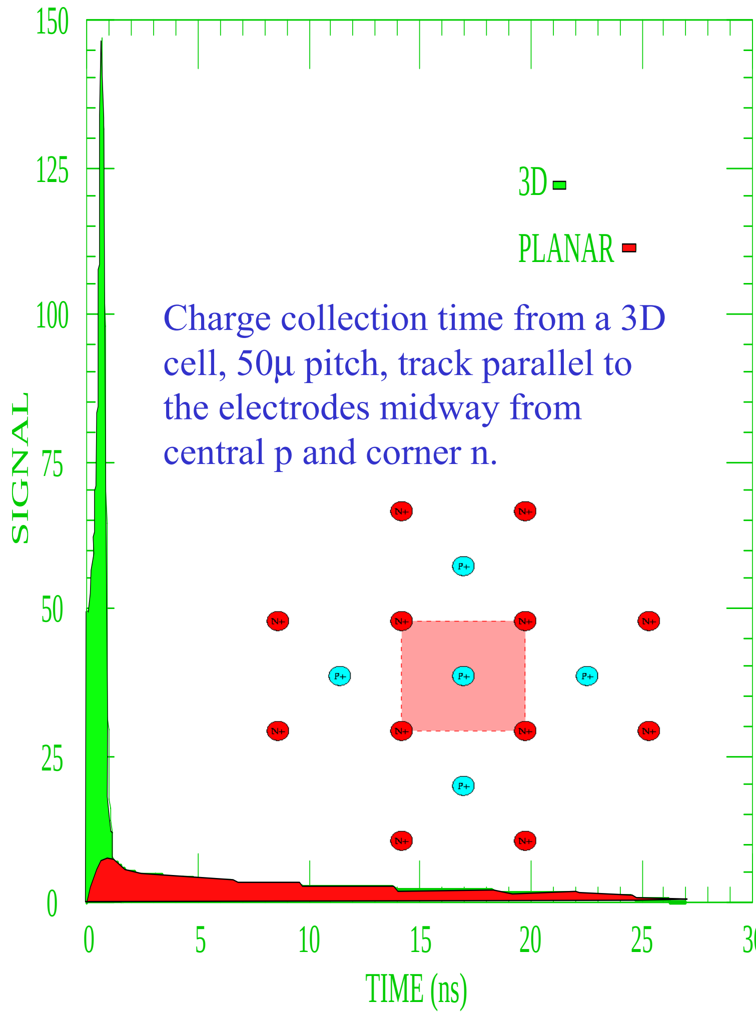
Drift field parallel to the plane of sensor.

- Signal pulse is about $\times 10$ faster than typical pixel.
- $V_{\text{depletion}} \sim 5\text{V}$.
- Flexible geometry (e.g. trapezoid).
- Active all the way to the edge (no guard ring).

Detector Development

Good timing!



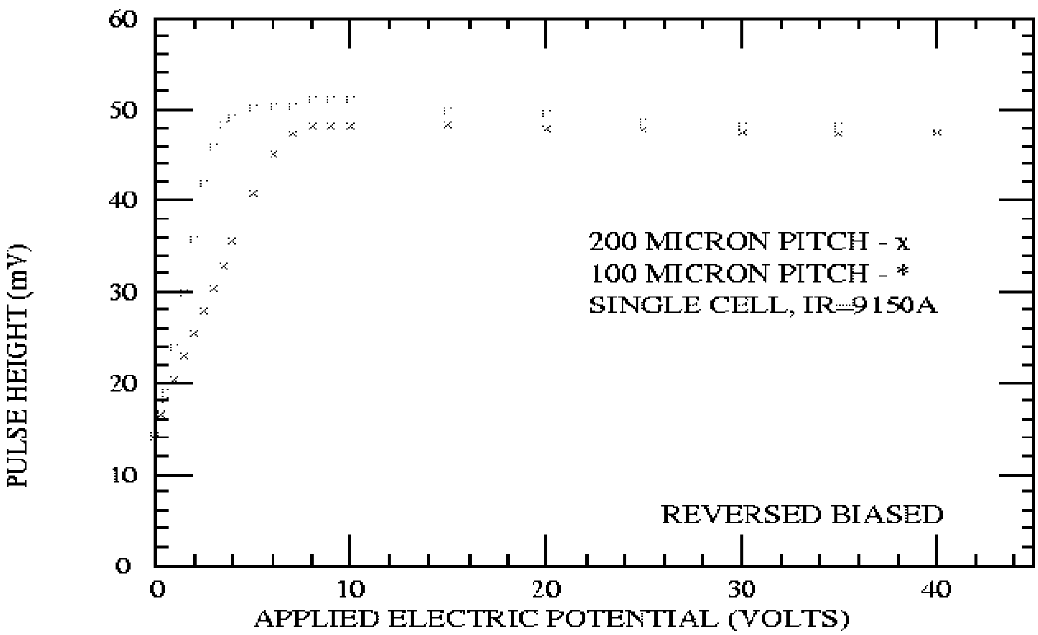


Reduction of distance between electrodes:

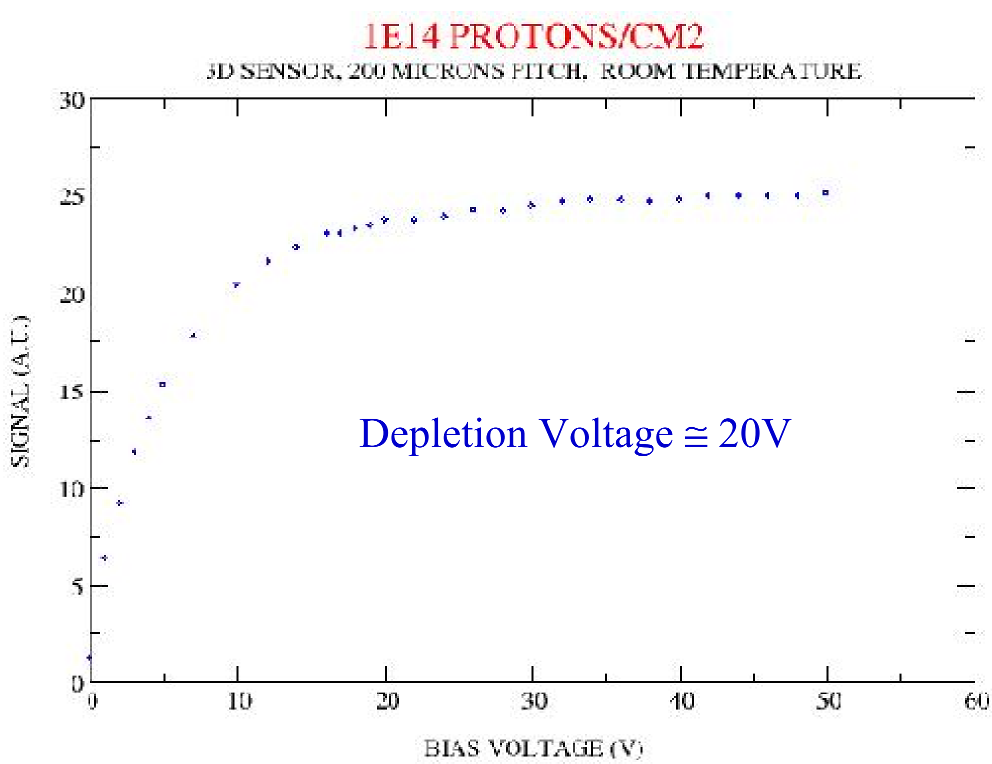
- Reduction of drift time
- Reduction of depletion voltage

Detector Development

IR tests show low depletion voltage



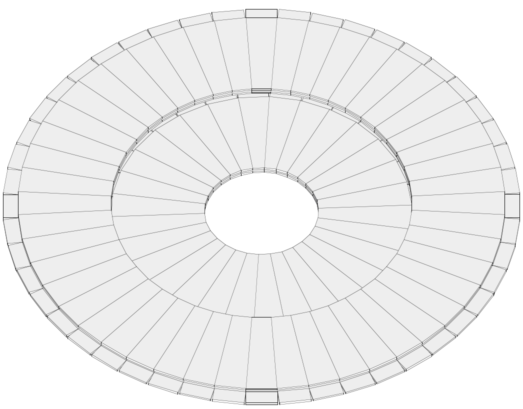
…also after 55 Mev proton irradiation



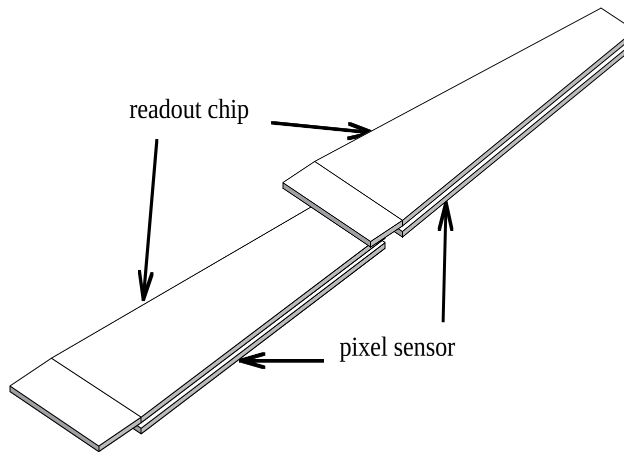
Pair Monitor Prototype

A set of 3D sensors currently in fabrication @SNF.

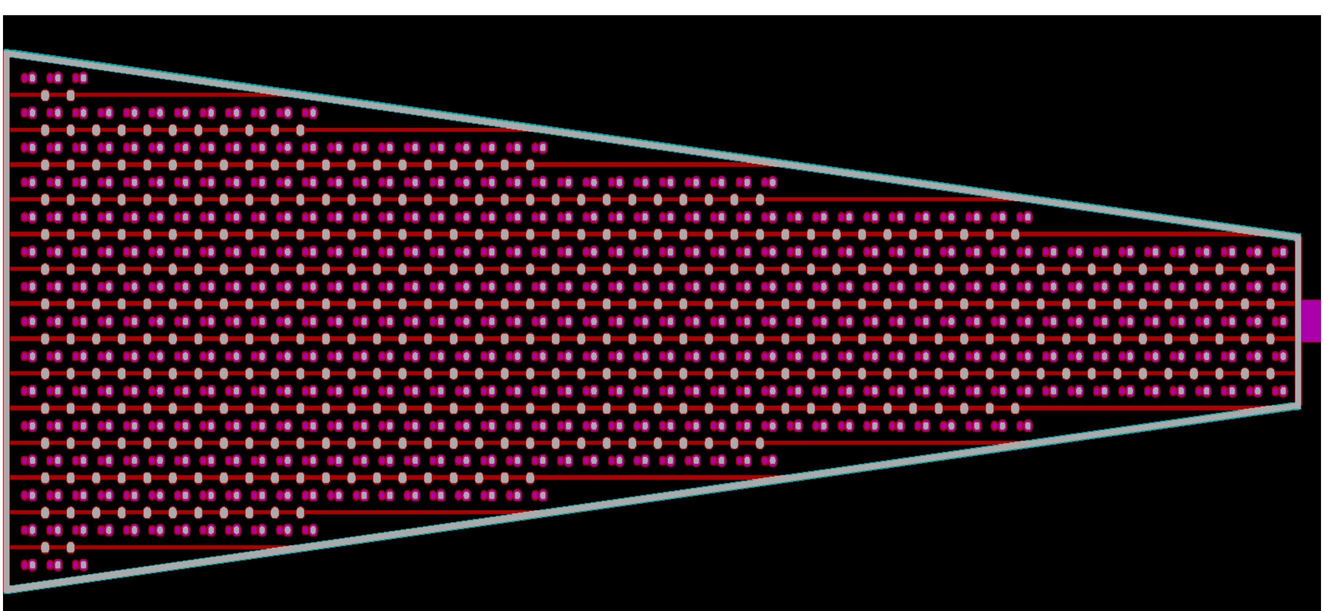
If all goes well, sensors available by the end of the year.



One disk showing the detector arrangement: top side facing the IP

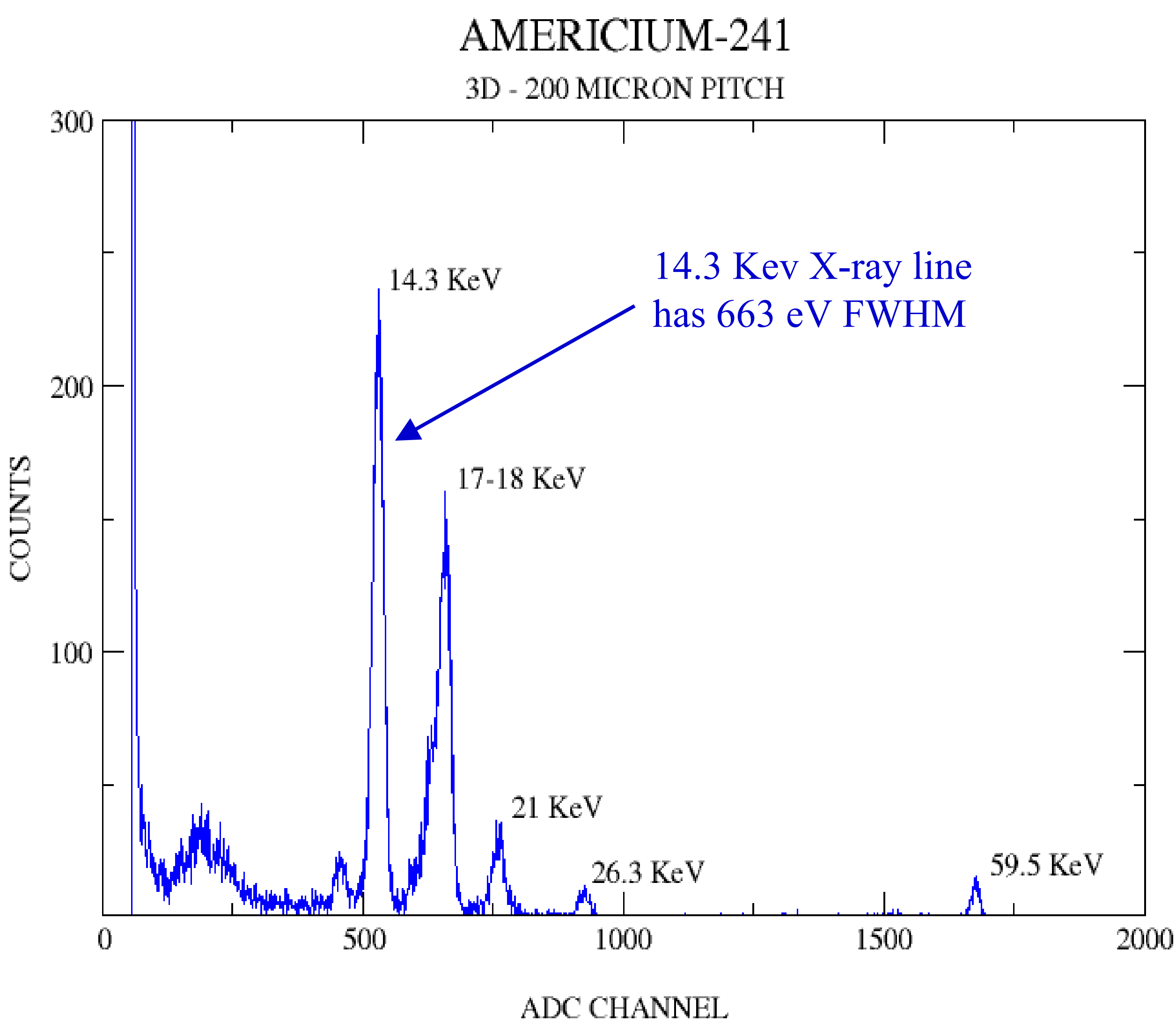


One trapezoidal component of the disk: sensor facing the IP



Detector Results - sensitivity

- Charge sensitive amp, 1 μsec shaping time
- "Strip detector" with 14 P-type electrodes tied
- 200 micron pitch strip to strip, 100 micron between electrodes within a strip

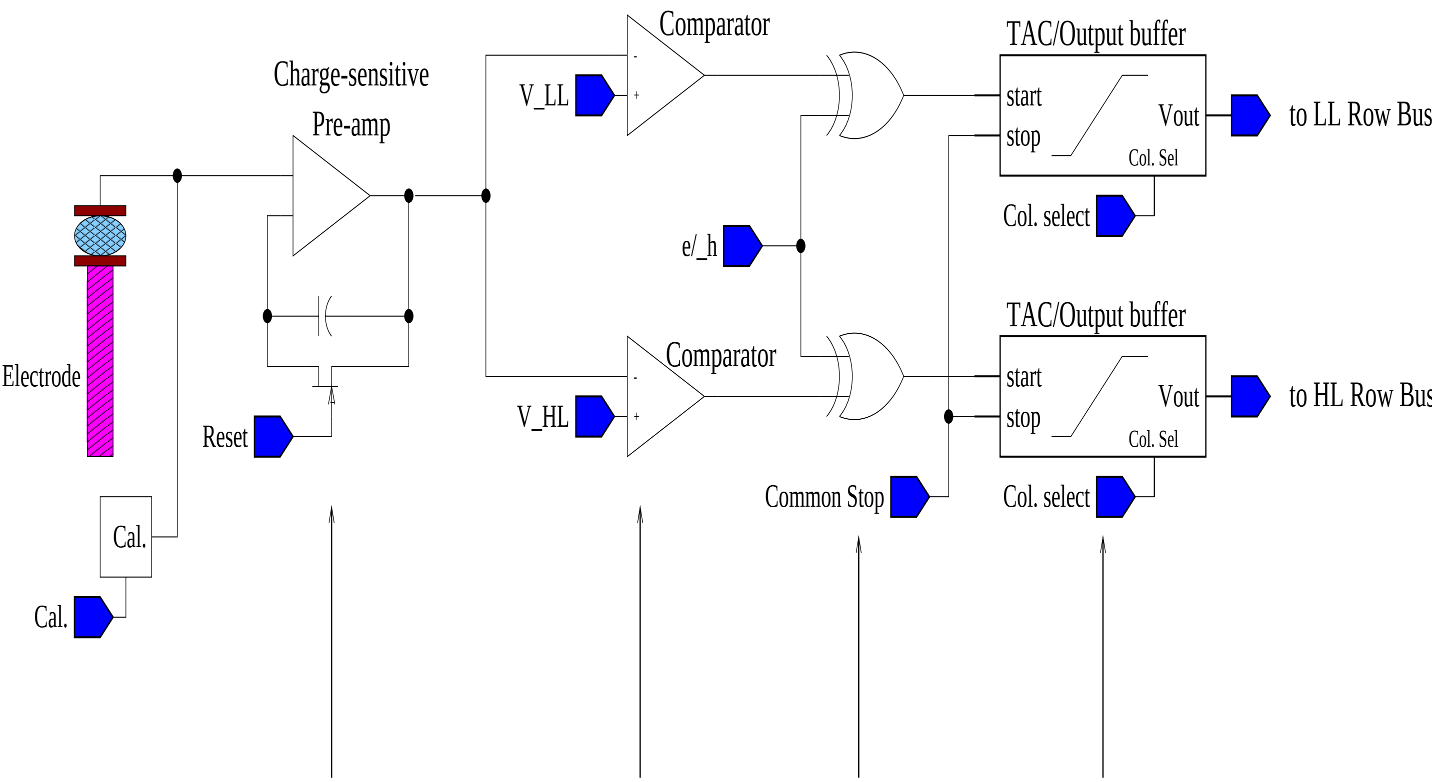


LCPIX0 Design Parameters

- Sensor Thickness (100/300μm)
  - Previous performance simulations based upon 300μm thick sensor, with 70keV threshold
  - Need simulation for thinner device (background rejection)
- LCPIX0 Design:
  - 100-300μm thickness (200-600 fF)
  - Good timing performance
  - Fit in 100 x 100μm footprint
  - Original spec. 5-15ns timing resolution
    - think can do better (see simulations)
  - Readout time target few ms (150 Hz trains)
  - 70keV Threshold

LCPIX0 Proposed Architecture

LCPIX0 Pixel Cell



Standard folded-cascode design

>= 1mV/keV gain

(>= 23mV/fC)

good timing performance

Standard topologies

V_LL = 25mV

V_HL = 50mV

Evaluate overdrive

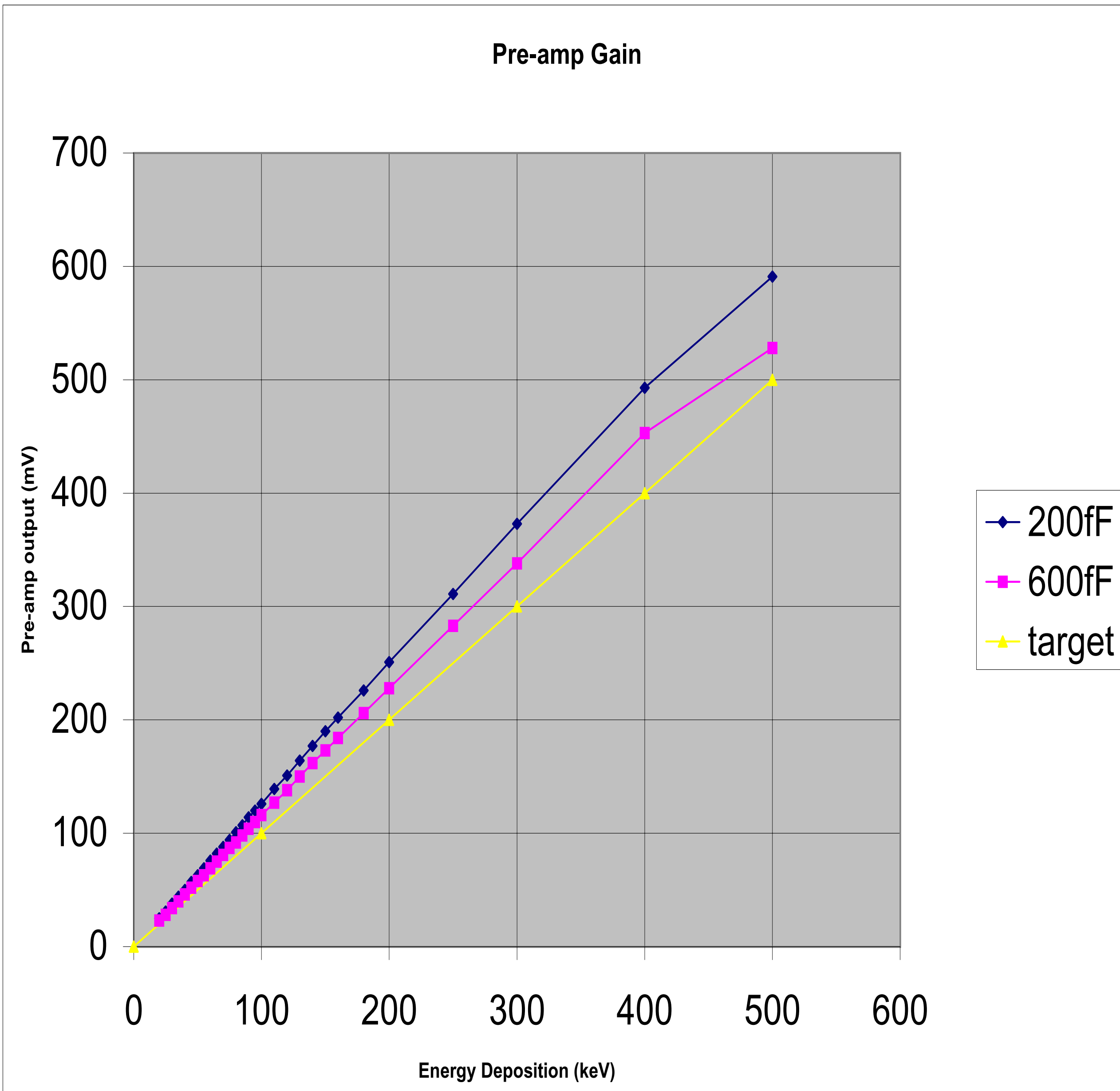
Can collect either holes or electrons

switched Isource into storage Cap

Common stop operation allows easy Zero Suppr.

LCPIX0
Pre-amp gain

Possibility of using 100µm or 300µm thick sensor

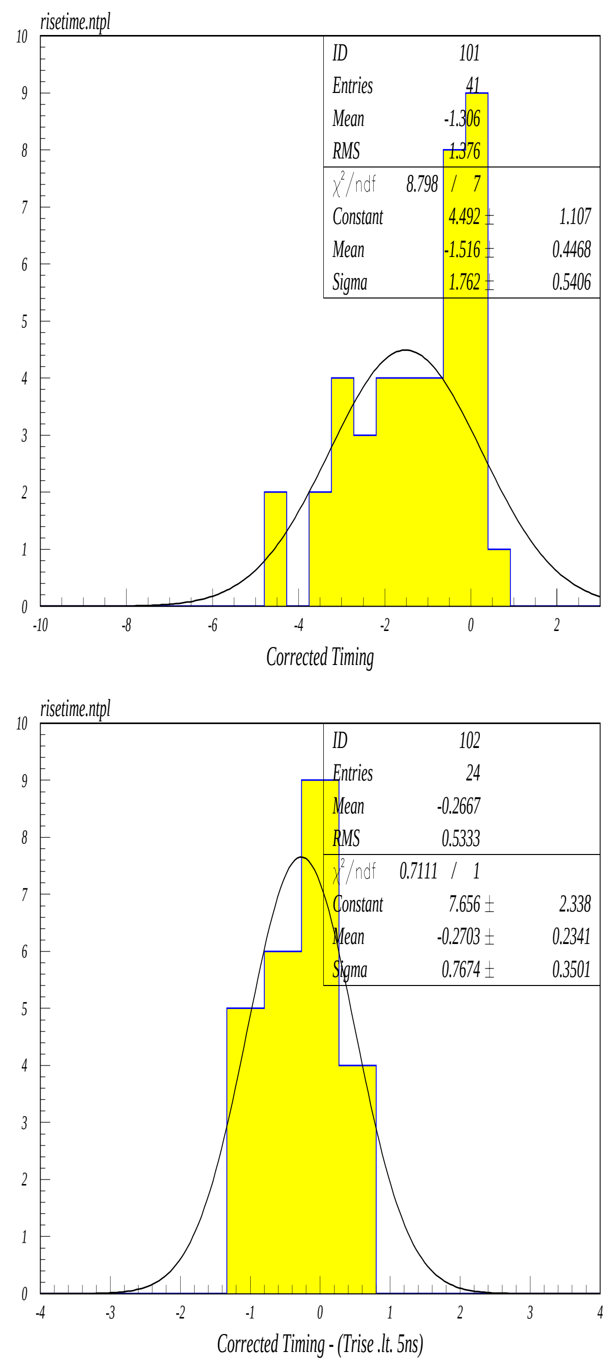


LCPIX0 Timing

With a time difference cut between T_{LT} and T_{HT} of less than 5 ns,

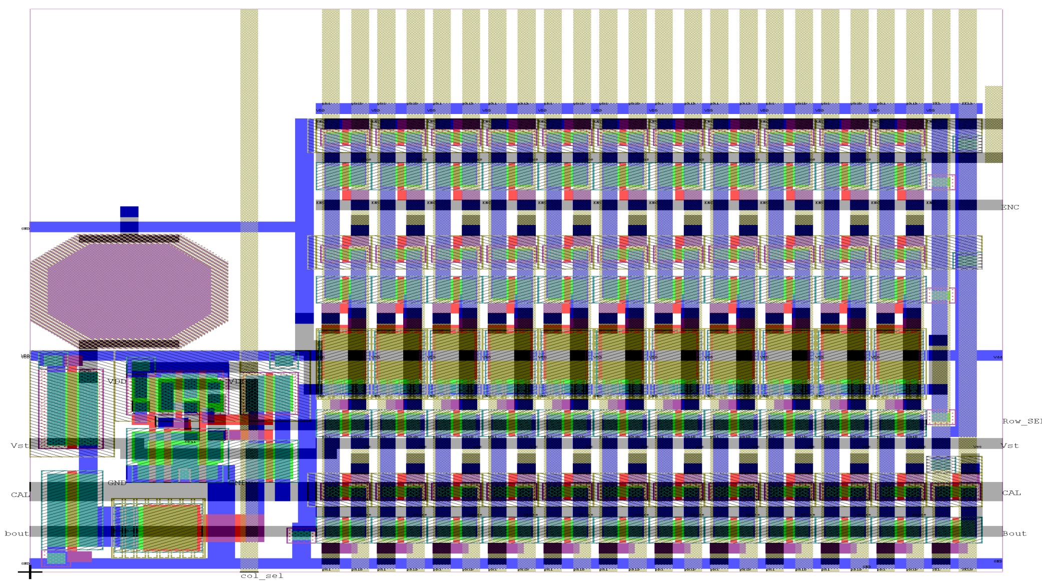
a time resolution of better than 1 ns on the bunch timing can be reached

LCPIX0 Final Corrected Timing



If occupancy is too high..

- External gating to set a window on a train
- Multi hit TDC on each pixel



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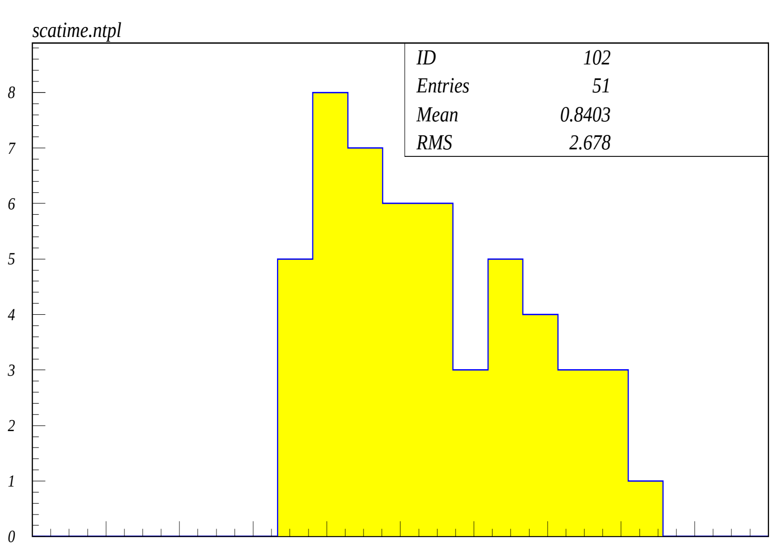
LCSCA0 Timing Residuals (70keV, full train)



With a multi hit TDC the timing resolution is better than 3ns, to be compared with a bunch separation of about 3 (1.5) ns

LCPIX0 To Do List:

- Further simulation
  - Next logical step is to check performance for a realistic energy/risetime distribution
  - Results seem "good enough" for now:
    - no apparent problem with C_i
    - can set a clean, 70keV threshold
    - ns level resolution should be possible
- LCPIX0 Design
  - Rest of readout architecture
    - check settling time good enough to readout in a few ms for full-sized sensor
  - Layout: to fit in 100 x 100μm footprint
  - Possible submission by end 2000?

Conclusions

For the beam profile monitor we need a position dependent counting detector:

- Set a 70 Kev threshold on each ch.
- Have a small charge sharing

⬇

3D sensor seems appropriate and preliminary results look encouraging

The proposed electronics allows bunch identification in a train and a full read-out between trains.