Simulations for SAMURAI-Si Silicon Detectors

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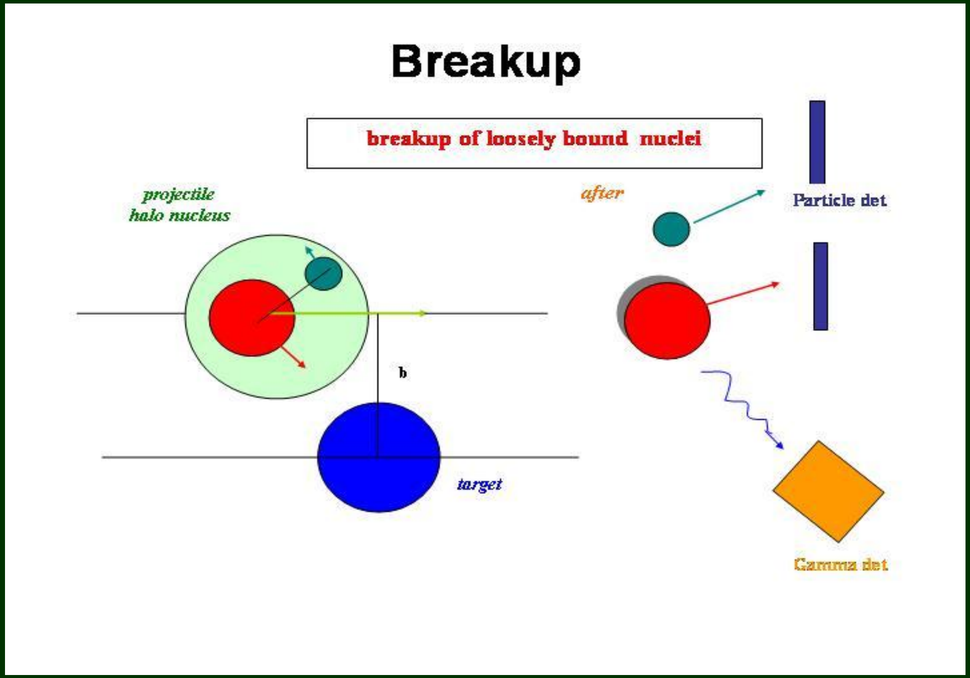
Overview

- Brief introduction to Physics – (more in Trache pres., Thursday)
- Geometric efficiency of silicon strip array
- Intrinsic resolution of SAMURAI-Si with DSSD – (2 dets) and with SSSD telescopes (~5 dets).
- Problem of Delta Ray Electrons
- Possible solutions
- DSSD (TTT) has 500 μm available thickness, difference?
- Discussion

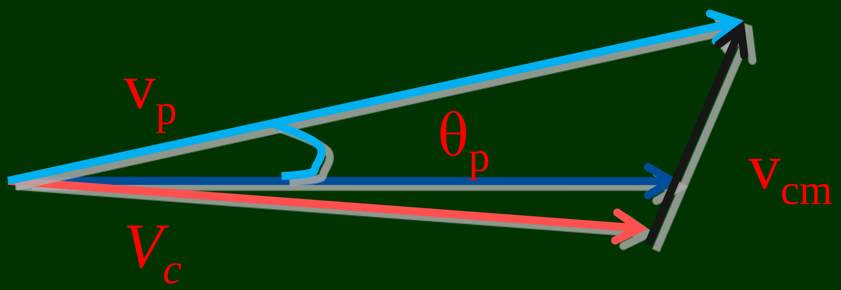
Physics Case for (γ,p) Measurements



- Coulomb and nuclear breakup measurements
  - Momentum Dist. gives nuclear structure info (ANC)
  - E_{rel} (both particles detected, M_{inv}), reaction mechanism
- More physics details in L. Trache talk – tomorrow

General Requirements for (γ,p) Measurements with SAMURAI

- Most vital for the physics interest is relative energies $E_{rel} < 1$ MeV.
- Opening angle for the proton for $E_{rel} = 1$ MeV :



$$E_{rel} \approx \frac{\mu}{2}\left[\left(\frac{v_p - v_c}{\gamma}\right)^2 + (\bar{v}\,\theta_{np})^2\right]$$

For $M_{core} >> M_p,\ v_c = v_p$

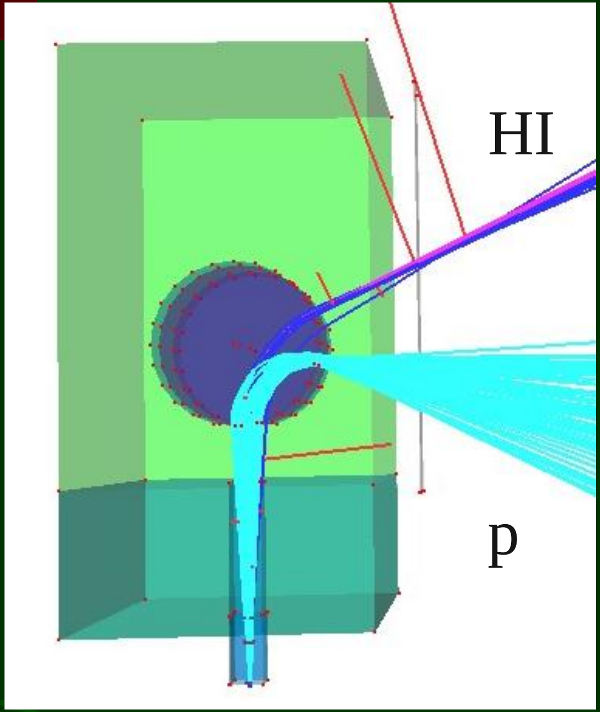
$$E_{rel} \approx \frac{\mu}{2}(\bar{v}\,\theta_{cp})^2 \approx E_p\left(\theta_p^{max}\right)^2$$

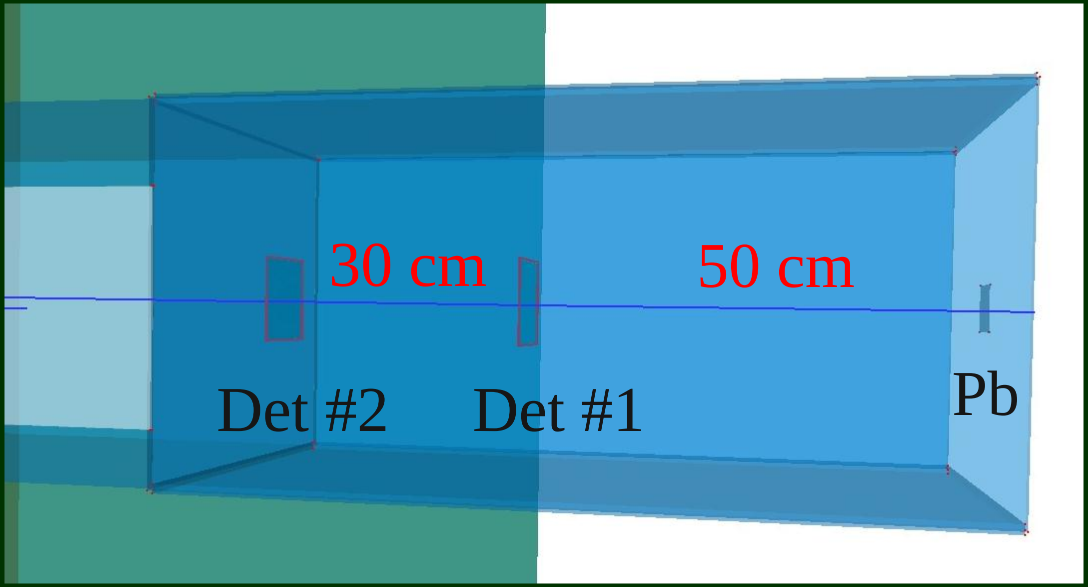
$$\theta_p^{max}(E_{rel}) \approx \sqrt{\frac{E_{rel}}{E_p}} \approx \sqrt{\frac{1}{250}} \approx 3.6°$$

- To cover this angle with 100 % efficiency at 80 cm from target, you need ≈ ± 5cm of coverage.
- DSSD (TTT) – 97.3 mm X 97.3 mm (100% at 773 mm from target)

  SSSD (GLAST) – 87.5 mm X 87.5 mm (695 mm from target)

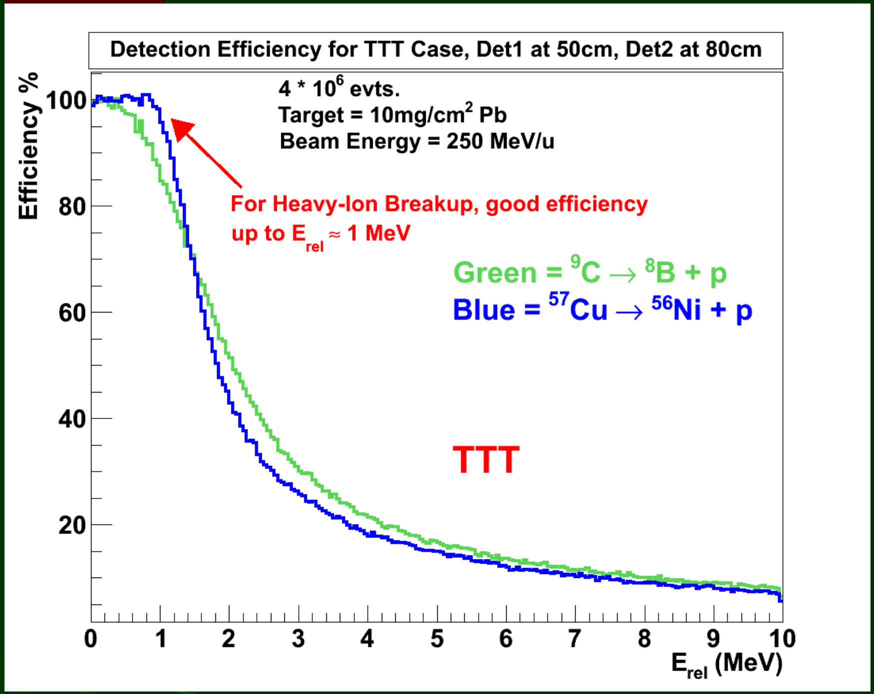
Simulation setup for Geo. Tests

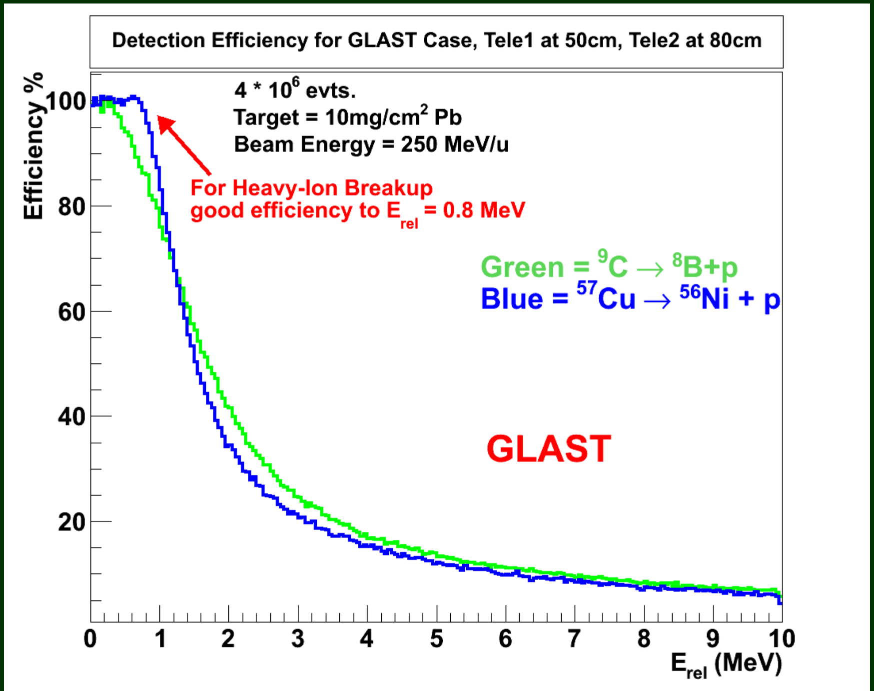




- Two detectors (or two telescopes) placed downstream of 10 mg/cm^2 Pb target at 50cm and 80cm (before SAMURAI).
- Simulate detection efficiency for SAMURAI - 90° for :
  - ^{9}C $\longrightarrow$ ^{8}B+p at 250 MeV/u
  - ^{57}Cu $\longrightarrow$ ^{56}Ni+p at 250 MeV/u

Geometric Efficiency Results



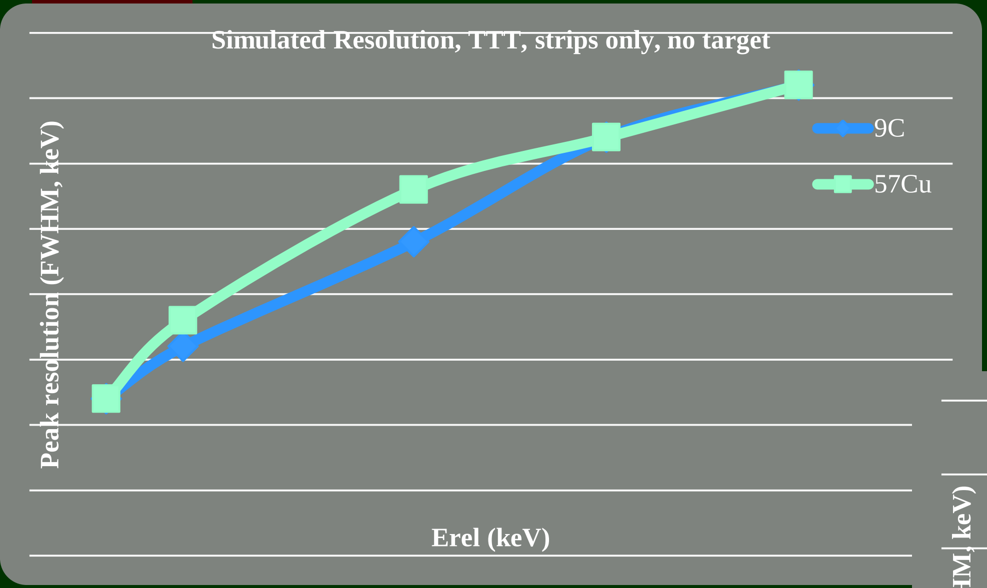


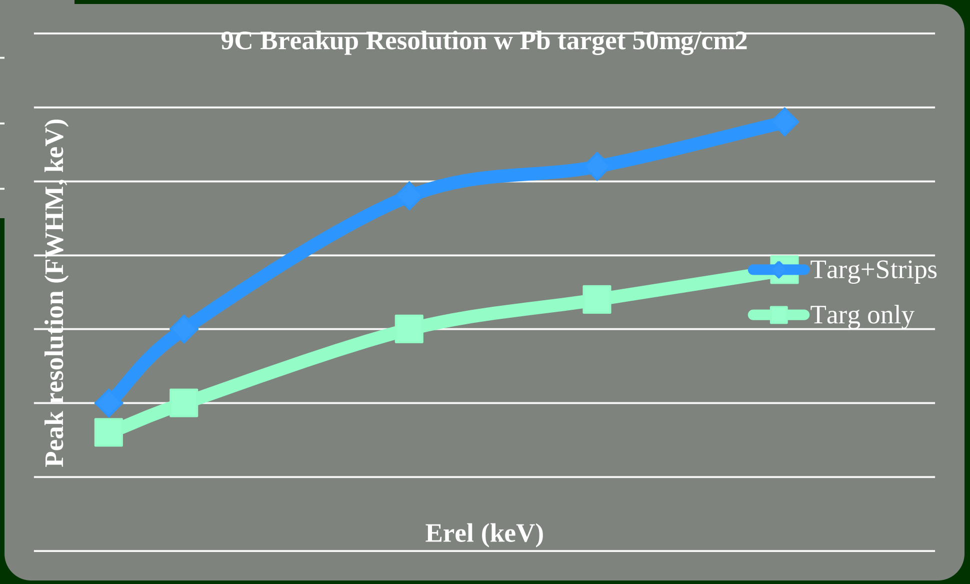
- Geometric efficiency slightly better for TTT case, but only because of larger active area (could move GLAST telescopes closer to target).
- Get expected (~100%) efficiency up to E_{rel} ~ 1 MeV.
- Noted that for $E_{rel} < 1$ MeV, no losses in SAMURAI magnet, even in high-res mode!

Resolution Simulations

- ~2 mrad angular resolution given with ~1 mm position resolution at 50 cm (detectors/telescopes at 50cm and 80cm from target!)
- 200 keV (FWHM) resolution at E_{rel} = 1 MeV desired.
- Fold in detector pixel resolutions
  - ♦ SSSD (GLAST) – 684 μm X 684 μm (3 x 228 μm)
  - ♦ DSSD (TTT) – 758 μm X 758 μm
- Correct for energy-loss in the detectors
- Does target thickness dominate resolution?

Results – resolution DSSD (TTT)





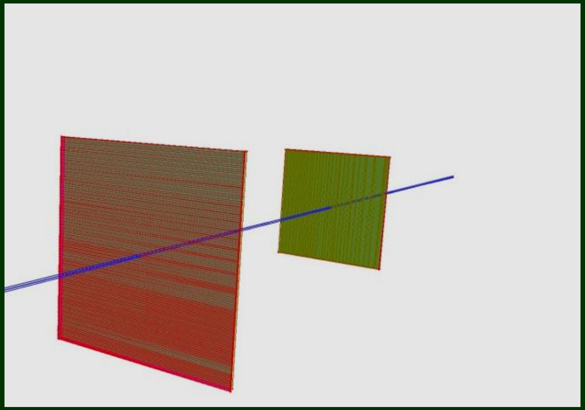
- Resolution specification met even with 50 mg/cm^2 Pb target!
- For thicker targets (> 50 mg/cm^2, resolution worse, dominates)

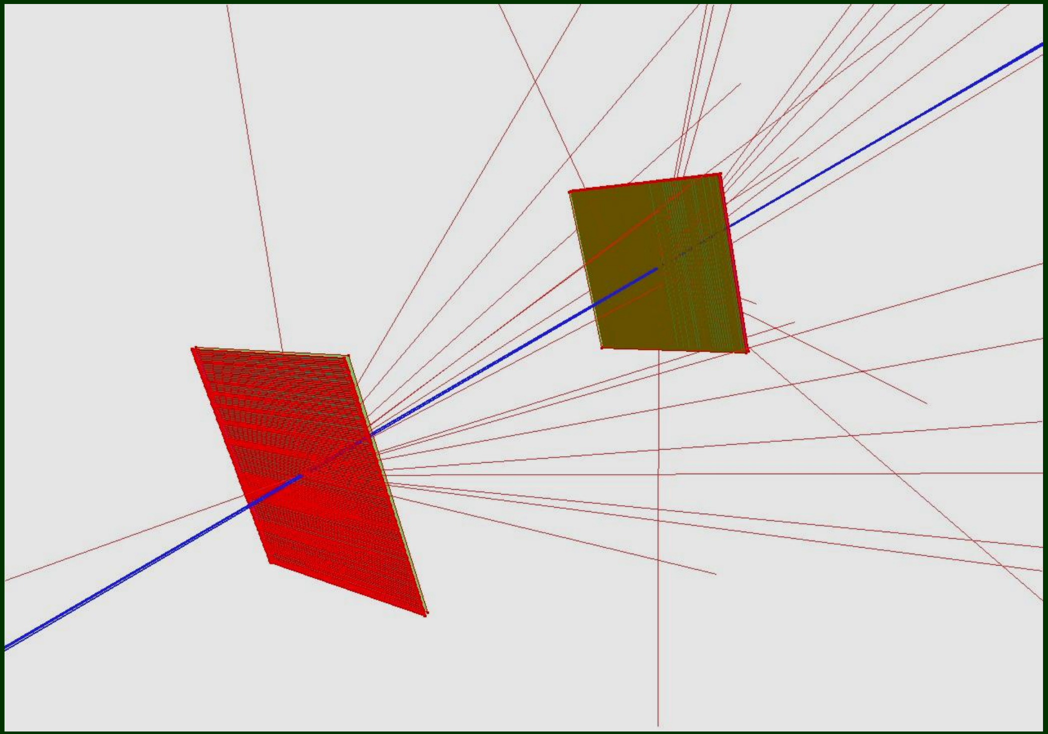
Delta Electrons

- Charged ions elastically scatter atomic electrons from materials (ionization).
- The maximum electron energy (kinematics) is ~ $(4m_e/M_{beam})*E_{beam}$
- For E_{beam} = 250 MeV/u, $E_{max}(e^-)$ ~ 550 keV.
- Energy deposited in Si 300 μm
  - ~250 MeV protons → ≈ 200 keV
  - ~550 keV e^- (1.66 MeV/g/cm^2) → ≈ 116 keV
- Number and angular distributions - Møller
- Could cause "cross-talk" and false "proton" events at these energies.

M. Pindo, NIM A 395, 360 (1997)

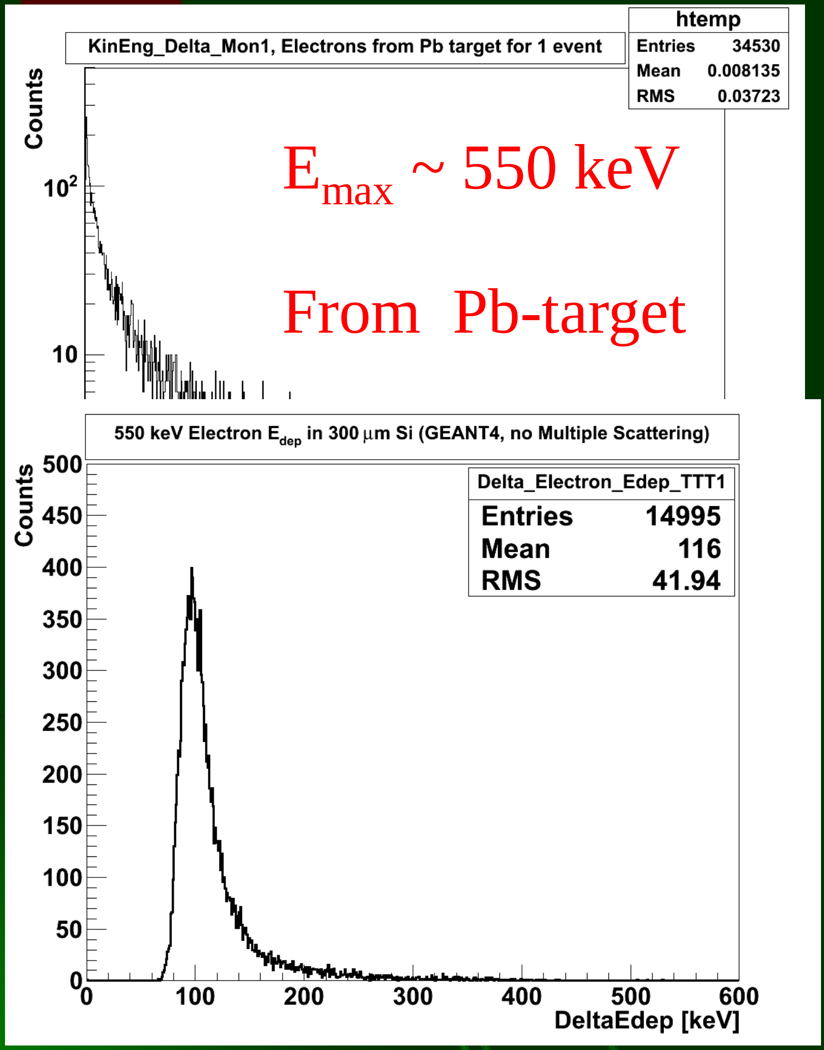
Delta Electrons in GEANT4

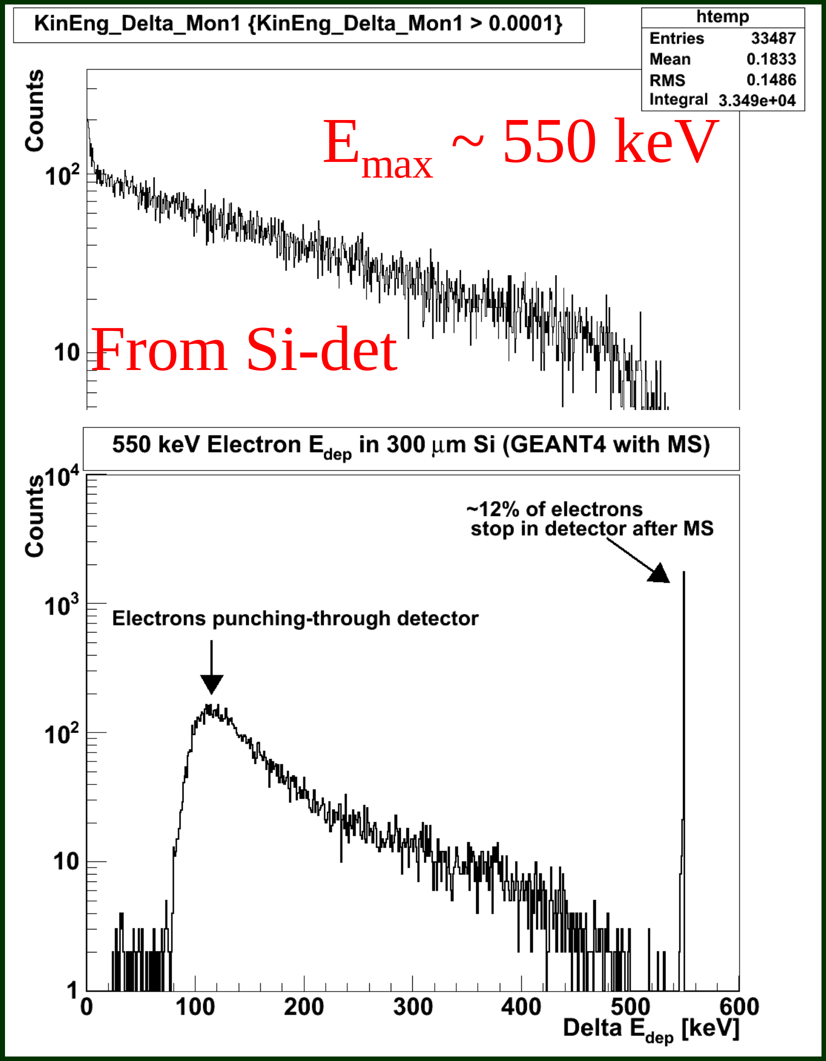




- Standard E-M models produce and track delta electrons if range cuts are reduced below 1 mm for electrons.
- Model produces deltas down to ~ 100 eV for range cut = 1 nm
- Møller scattering is used.

Validation of GEANT4 for Delta Electrons

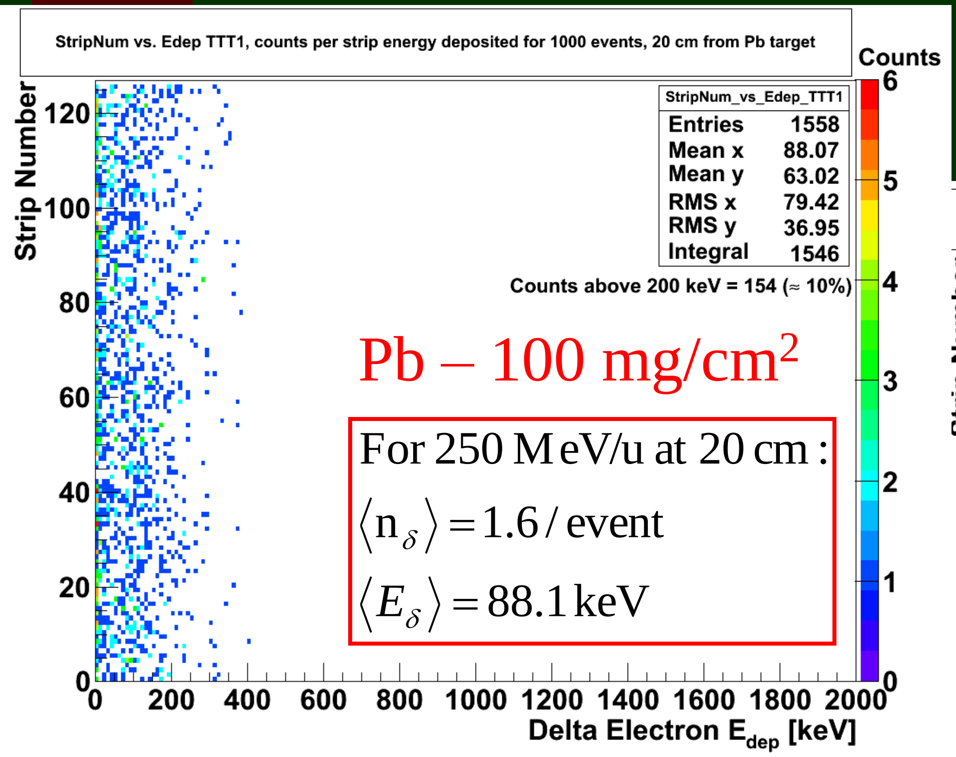


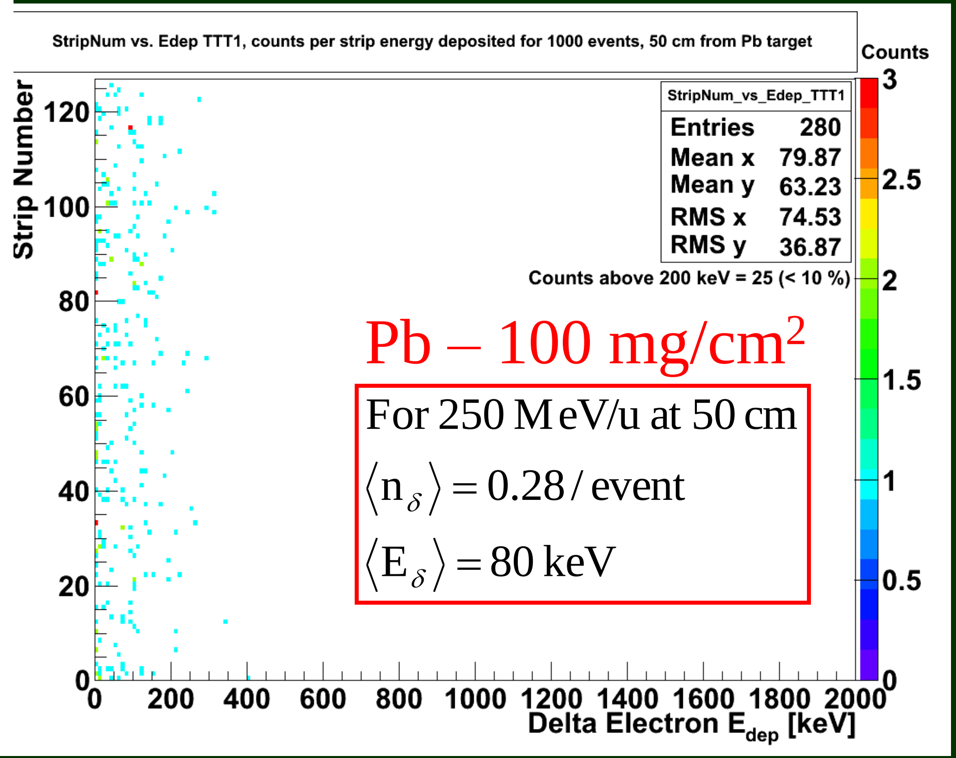


- GEANT4 reproduces energy distributions, losses in Si

Deltas from Pb Target

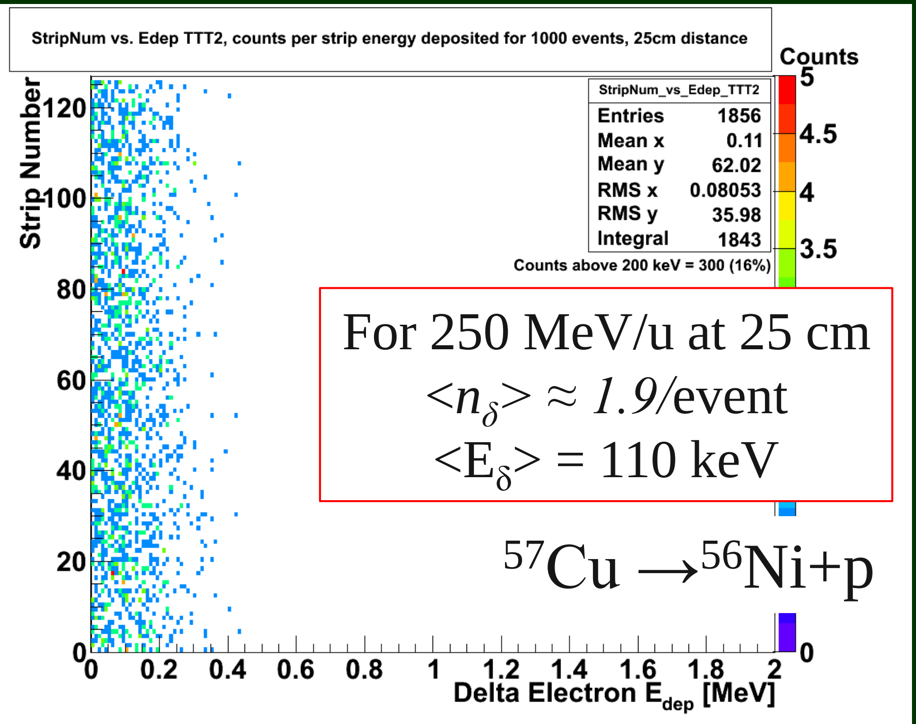
Reaction: $^{57}Cu \rightarrow ^{56}Ni + p$ at 250 MeV/u

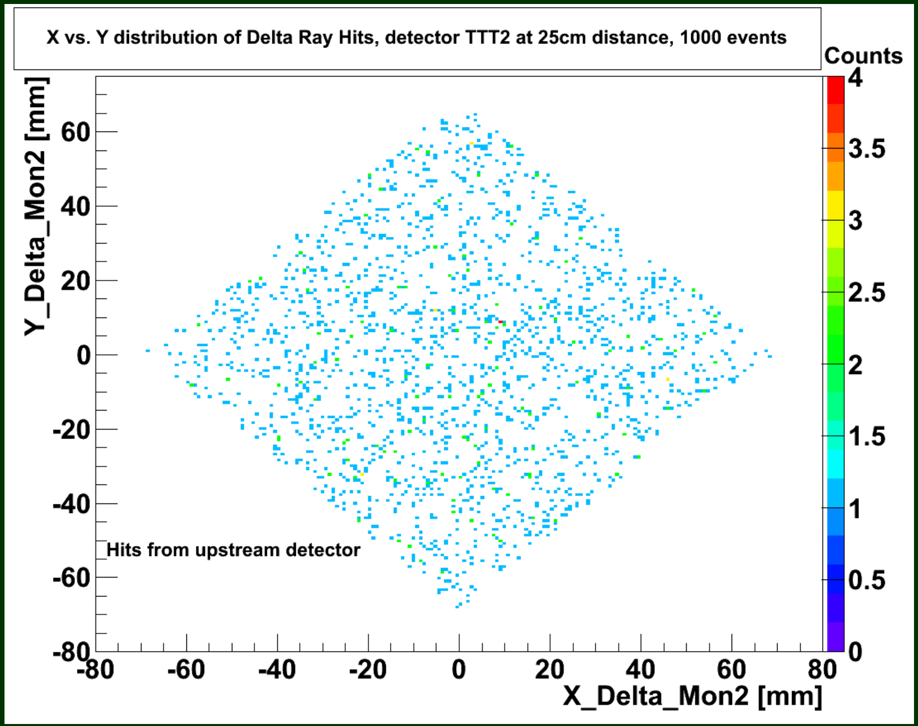




- Delta electron from target not too much problem if first detector/telescope is far enough downstream.

Deltas from the Detectors - DSSD

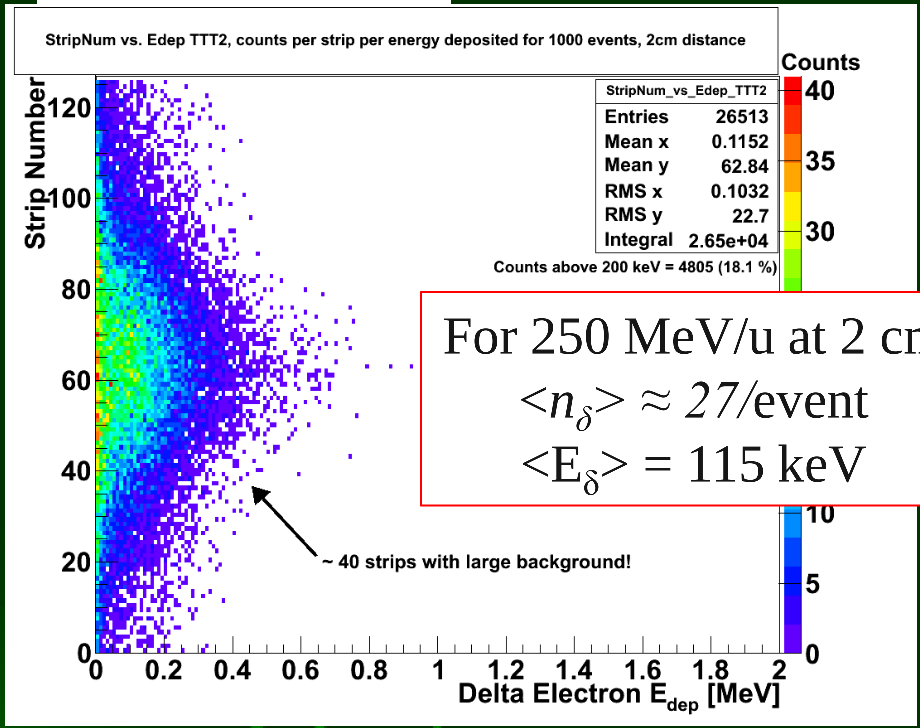




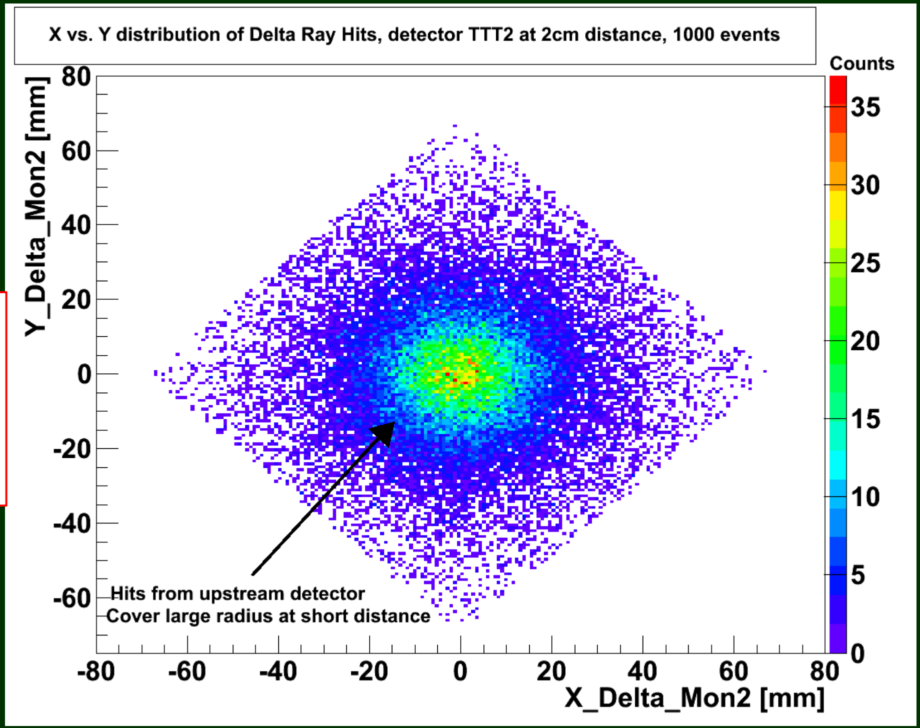
- At 25cm distance, most of the deltas (84 % per event, are depositing below 200 keV).
- Delta electrons from upstream detector are uniformly distributed.

Deltas from the Detectors – SSSD

$^{57}Cu \rightarrow ^{56}Ni + p$

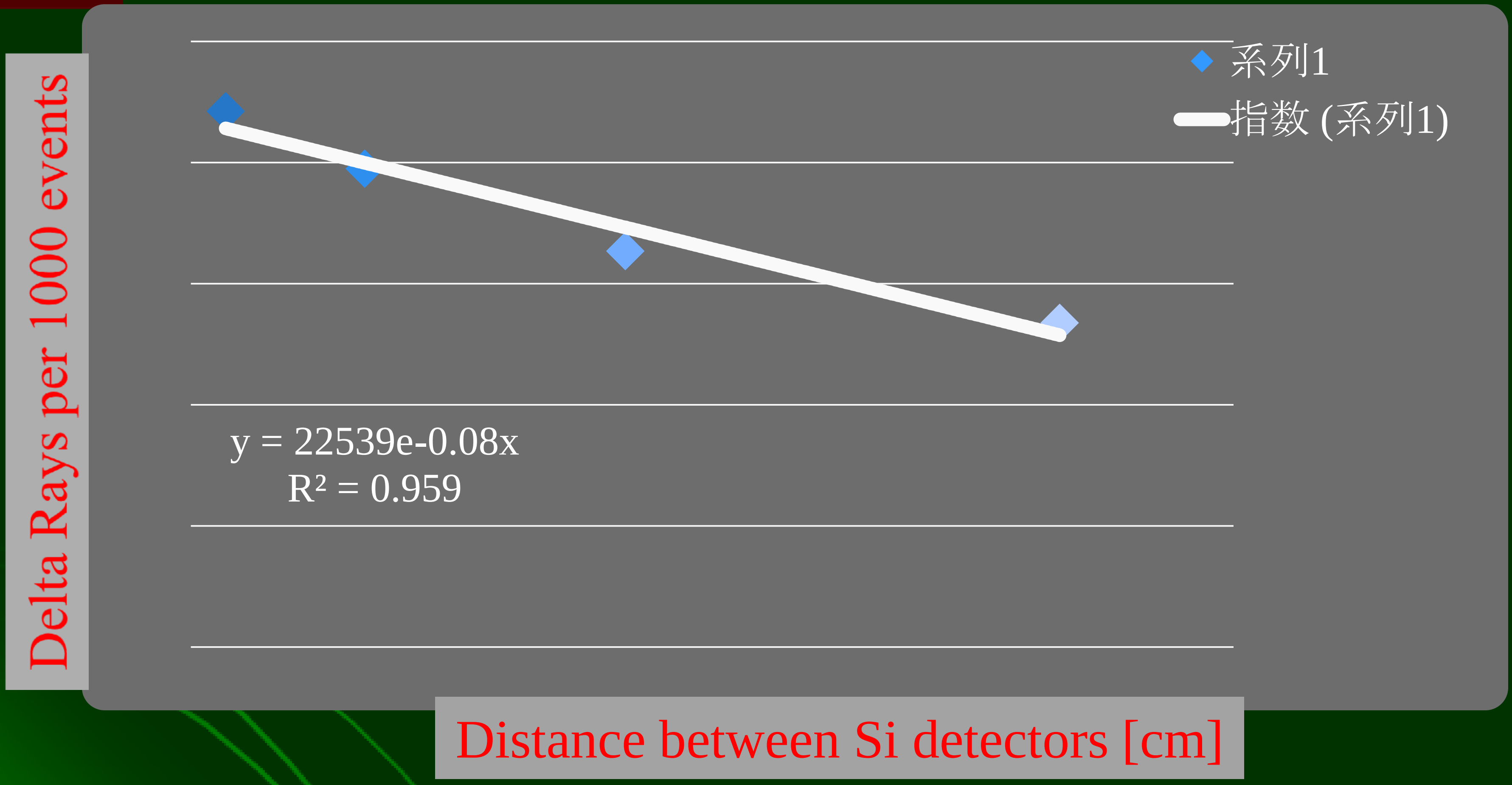


For 250 MeV/u at 2 cm
$\langle n_\delta \rangle \approx 27$/event
$\langle E_\delta \rangle = 115$ keV



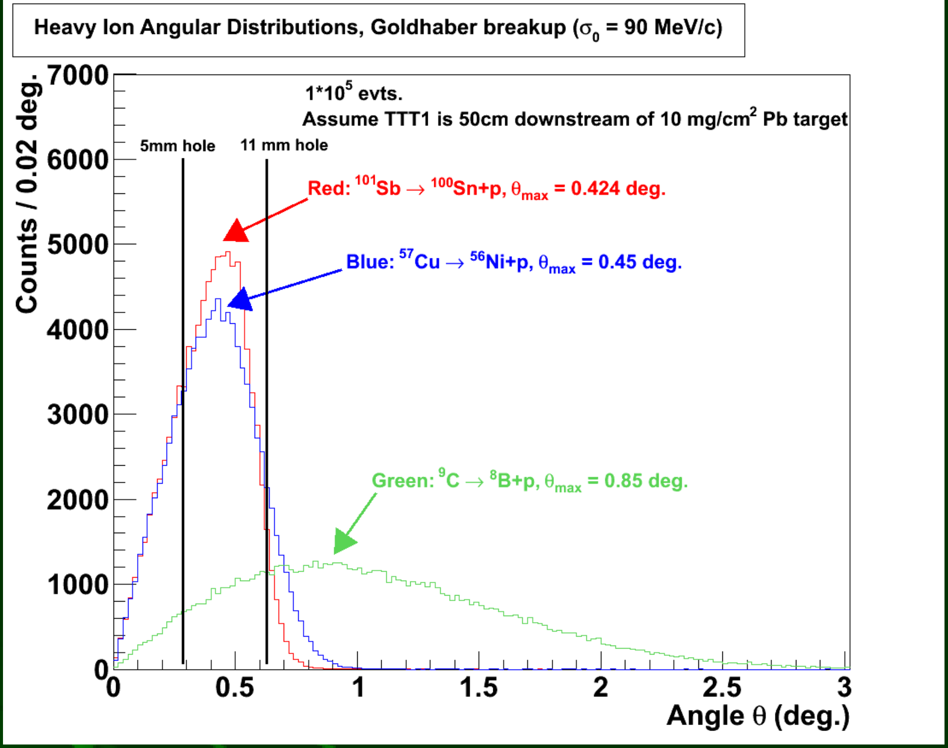
- For the SSSD (GLAST) case, requires 2 or more detectors in close proximity (single-sided) → lots of delta electrons!

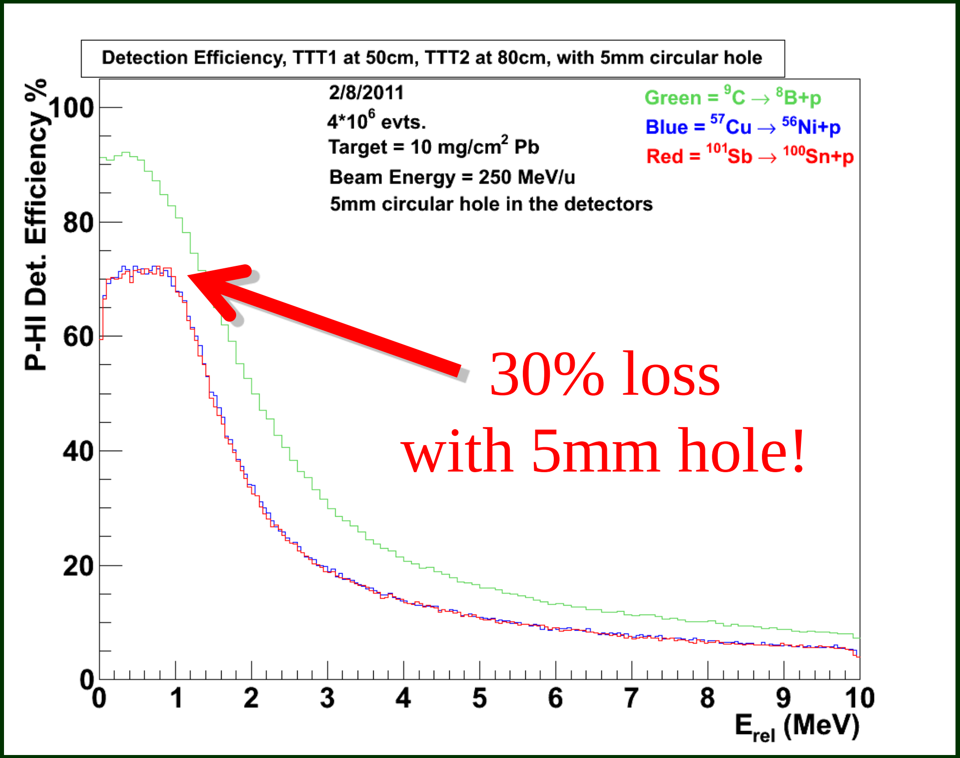
Detector distance vs. # of δ-rays



- Safest option would be with DSSDs (TTT) at large dist.
- If SSSD (GLAST), can the detectors be further apart?

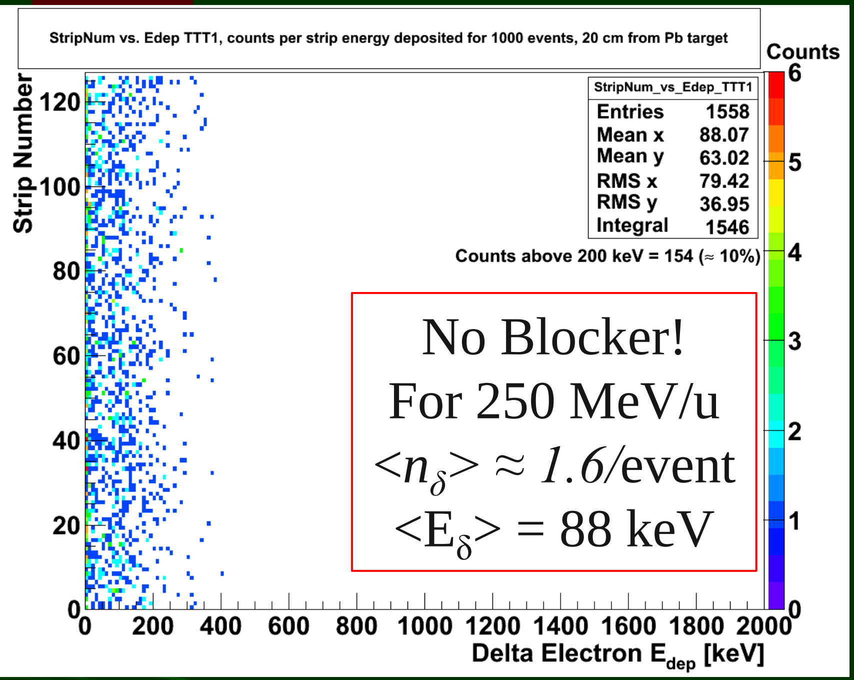
Possible Solutions

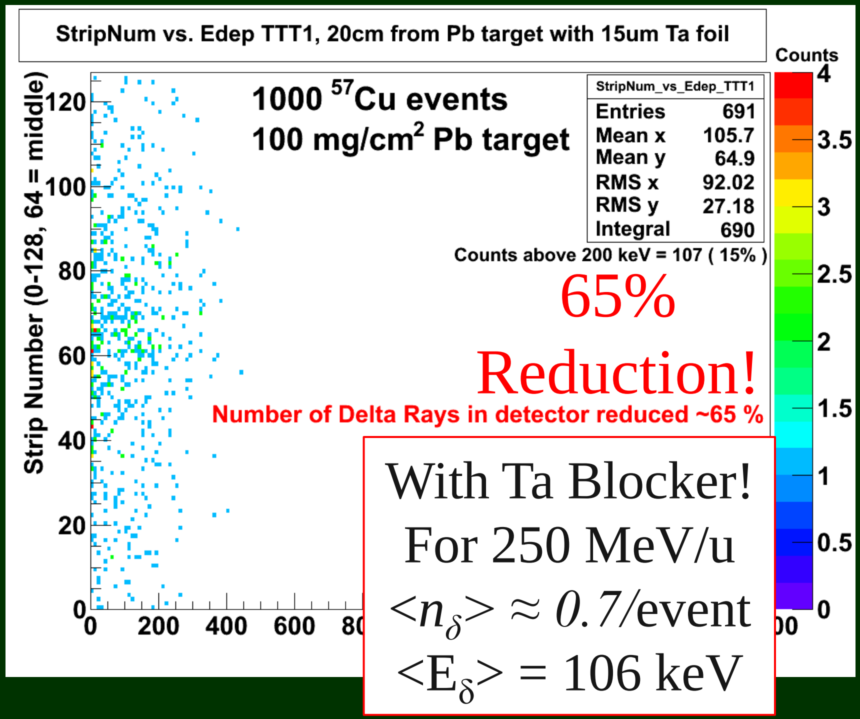




- Assume 10 mm diameter beam (best case?)
- Simulate detector with a hole for the beam.
- Lose detection efficiency!
- Still have deltas from breakup events (more sims. needed!)

Ta – Blocker with a hole



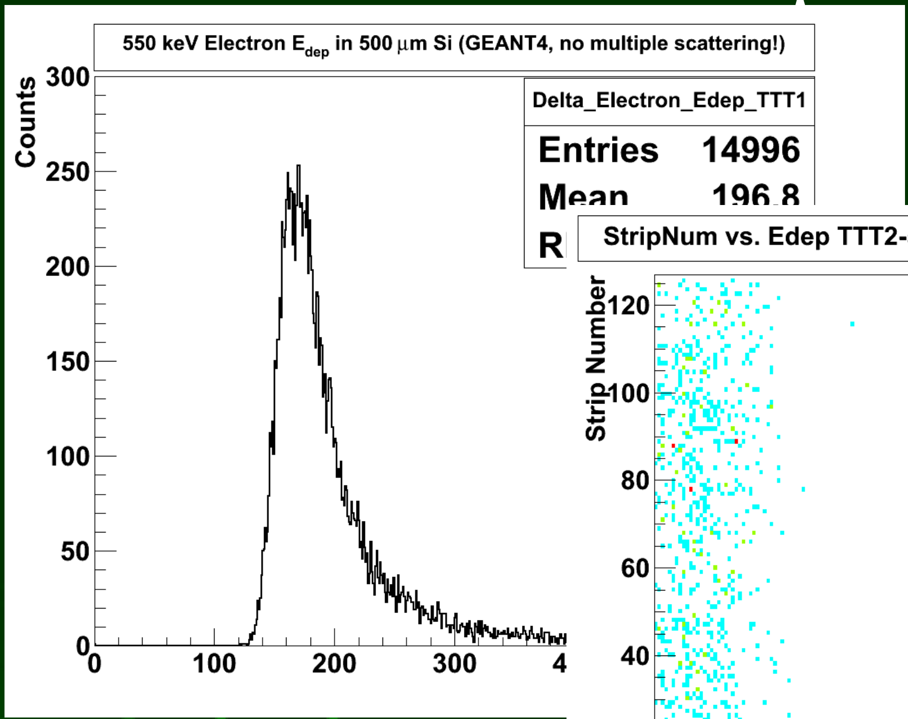


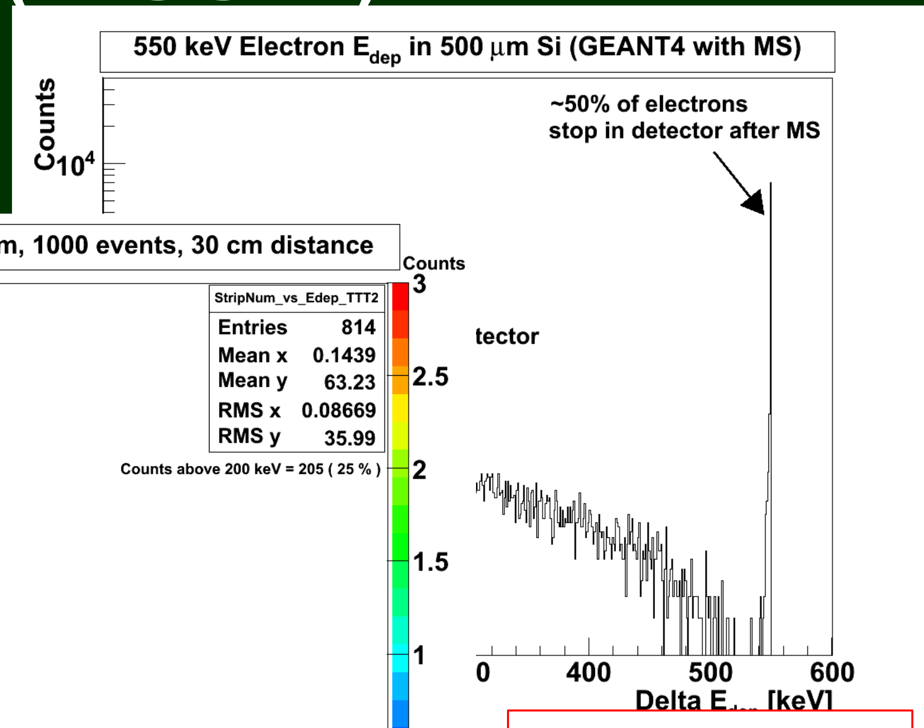
- 15 μm Ta with ~10mm diameter hole for beam to pass
- Reduces delta electrons (65%), but acts as an additional "target" on the proton and the core, reduces resolution.
- Will try this solution in the in-beam test at TAMU.
- May test other materials, kapton?, scintillator?

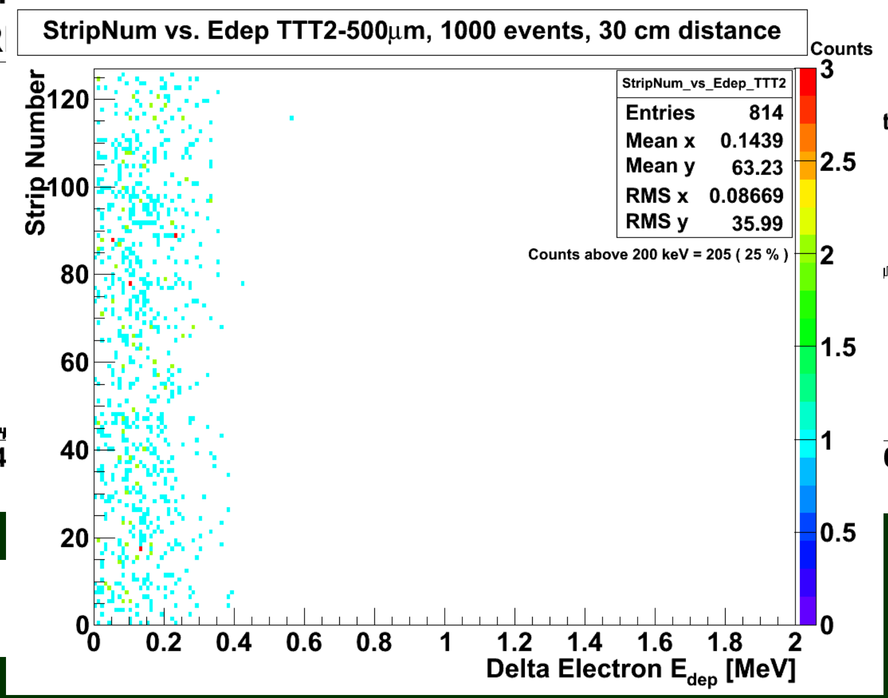
If DSSD (TTT), what about 500 μm?

- Currently, threshold on TTT-300μm is ~350 keV (see R. Shane).
- Typical Proton energy deposit for in 300 μm for E_p = 250 MeV
  - E(deposited) ≈ 200 keV, 150 keV – 250 keV range.
  - Well below electronics threshold.
  - Close to main background from the delta-electrons.
- Expect similar or better threshold with thicker detector, but more ΔE from proton, easier to separate signal from noise, bkg.
- Typical proton energy deposit in 500 μm Si for E_p = 250 MeV
  - E(deposited) ≈ 340 keV, 250 keV – 450 keV range.
  - With improved electronics threshold, more reasonable.
- Resolution should be the same (depends on strip pitch!)
- Delta electrons ?

Delta Ray threshold with TTT-500μm (DSSD)







$^{57}Cu \rightarrow {}^{56}Ni+p$

500 μm DSSD
For 250 MeV/u
$<n_\delta> \approx 0.8$/event
$<E_\delta> = 144$ keV

- 500 μm Si = 0.116 g/cm^2 → e^- $E_{dep} \approx 193$ keV.
- Delta e^- threshold safe around ~200 keV. Can correlate event after magnet.

Conclusion and Discussion

- GEANT4 simulations of 1p breakup indicate :
  - Good detection efficiency for Si detectors up to E_{rel} = 1 MeV.
  - Good resolution in relative energy even with a thick Pb target!
- However, having detectors at 0° in beam is challenging.
  - Delta electrons have energy deposit similar to protons!
  - Lots of them!
- Possible Solutions to delta electrons
  - Larger separation - best
  - Detectors with hole – efficiency loss!
  - Ta foil – resolution loss – acts like another target!
- Should we go to thicker detector (DSSD - TTT – 500 μm) ?
  - More energy deposit from proton
  - Similar delta electron problems
  - ? Electronics Threshold

Thank you for your attention !