Data analysis II:
GEM tracking and background

Addressing Charges 4 & 7

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LAD ERR
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Why use GEMs?

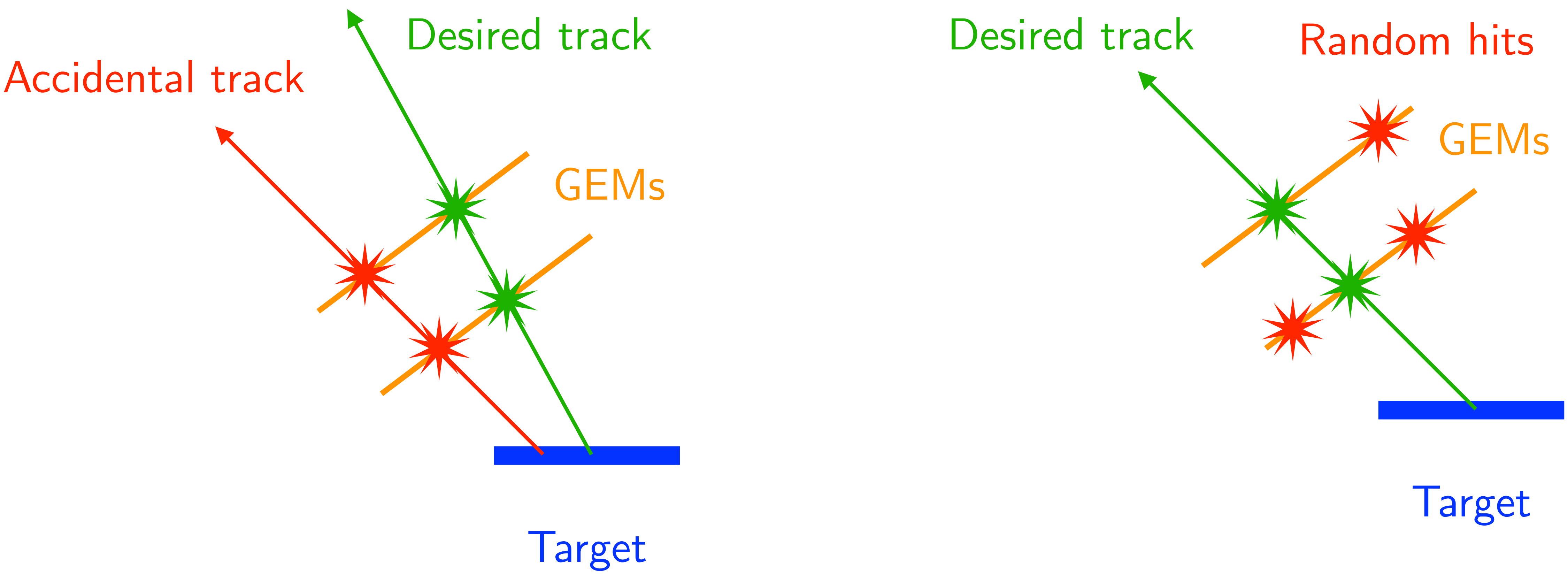
- The LAD measurement is background-limited
- Use GEMs to perform tracking/vertexing to reduce background
- This can be used to extend kinematic reach or reduce uncertainty

Some GEM details

- Two GEM detectors allow independent tracking (no need for LAD hits)
- Will use existing PRad GEMs (55 cm x 122 cm)
- GEM planes at 127°
    - GEM1 is 75 cm from target
    - GEM2 is 95 cm from target
- Where necessary, assume:
    - GEM position resolution $\leq$ 100 microns
    - GEM readout window = 40 ns

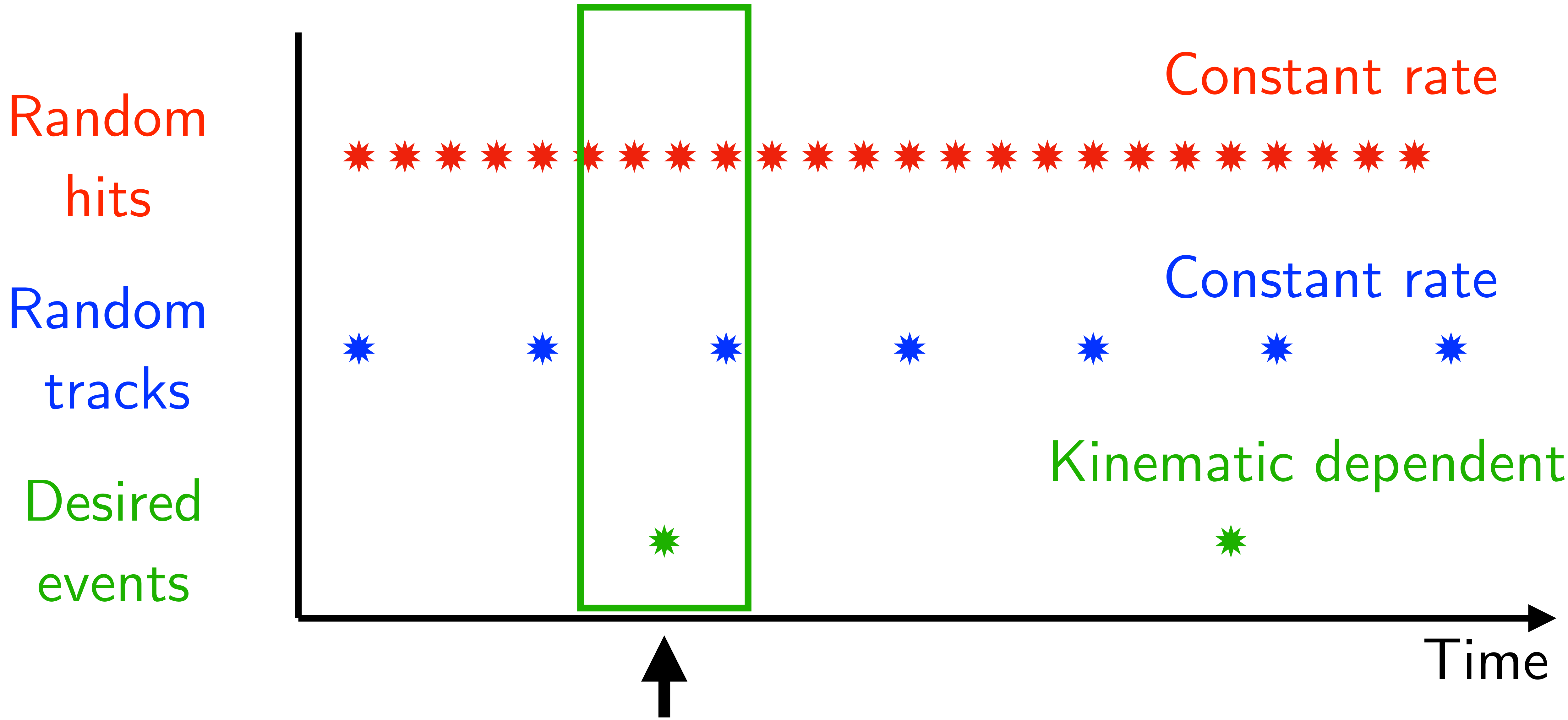
GEM background

- GEMs are at large backward angle, but very close to target
- Could random background (from photons, electrons) limit the GEMs ability to eliminate accidental tracks?



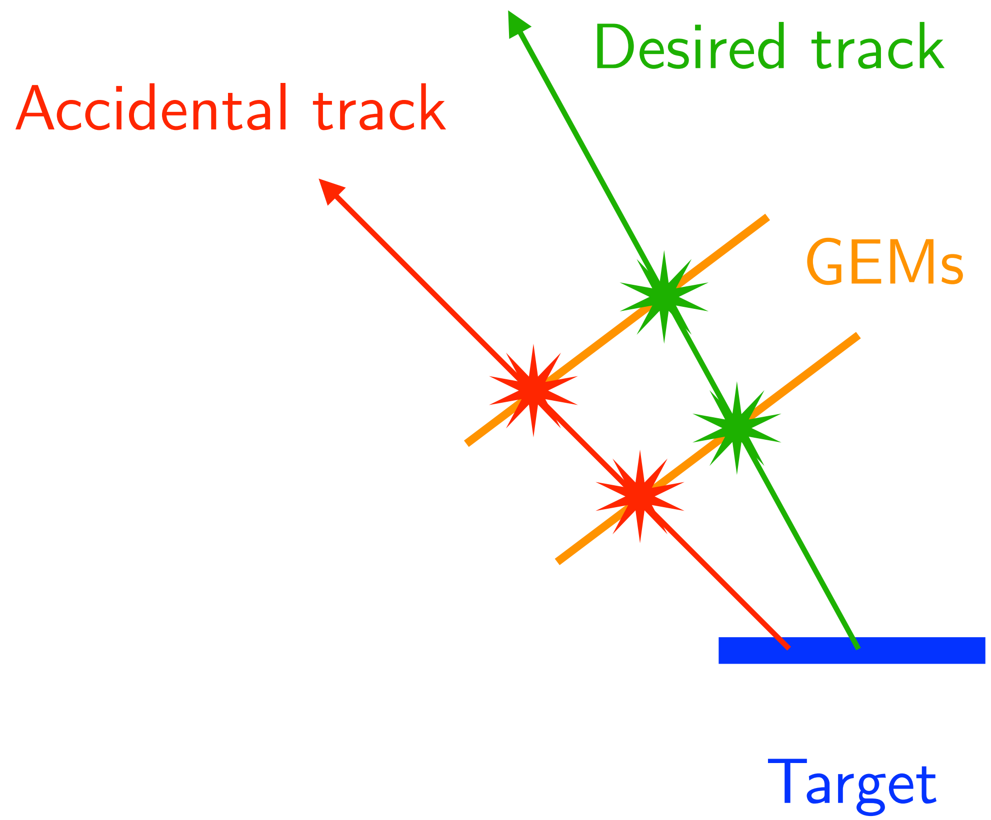
For anticipated random background rate of up to several GHz, vertexing cuts are able to identify desired track 90% of the time

Estimating background



Need to account for all background occurring around event trigger

Estimate number of *random tracks*

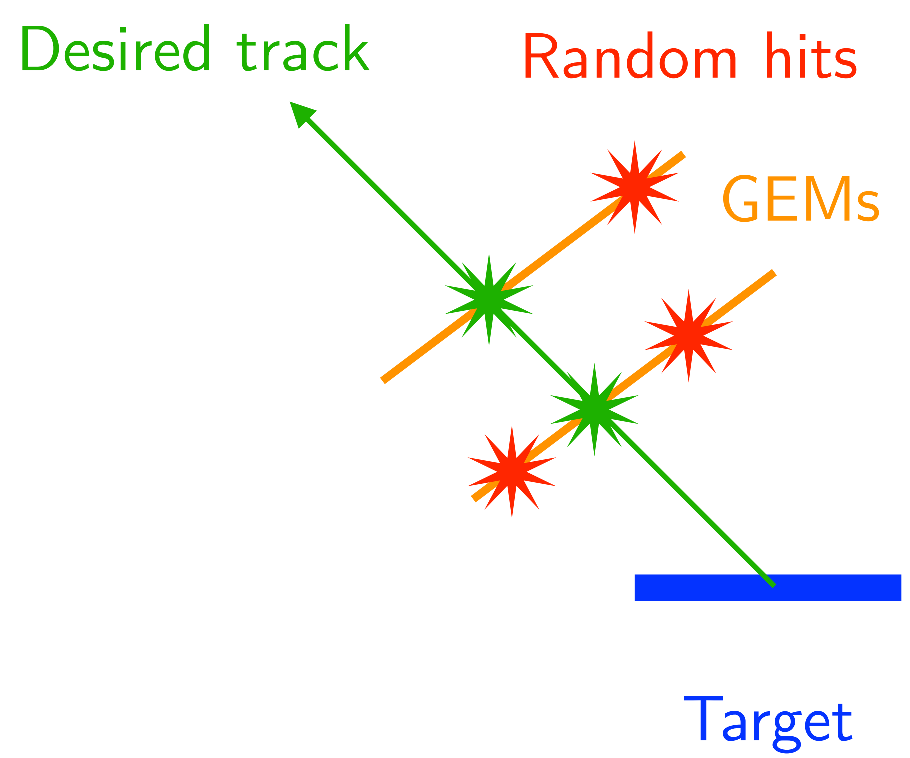


- Expect LAD/GEM proton rate of approximately 20 MHz (estimate from proposal for 1.2 x 10^{37} cm^{-2} s^{-1} luminosity)

20 MHz x 40 ns = 0.8 random tracks

Round up to *1 random track/event*

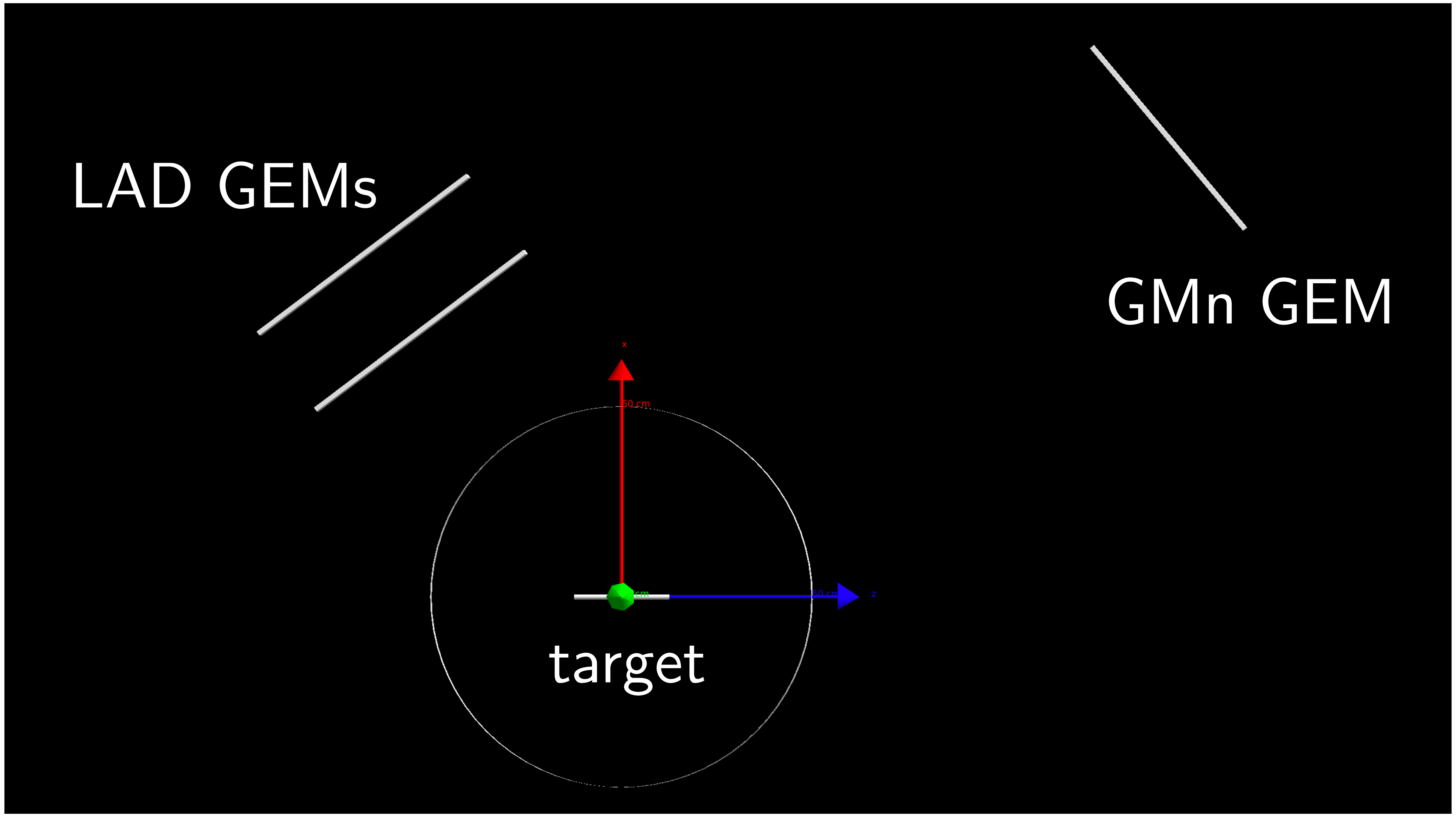
Estimate number of *random hits*



- What is the background flux leaving target?
- What is the background flux actually reaching the GEMs?
- How many of these particles are detected by the GEMs?

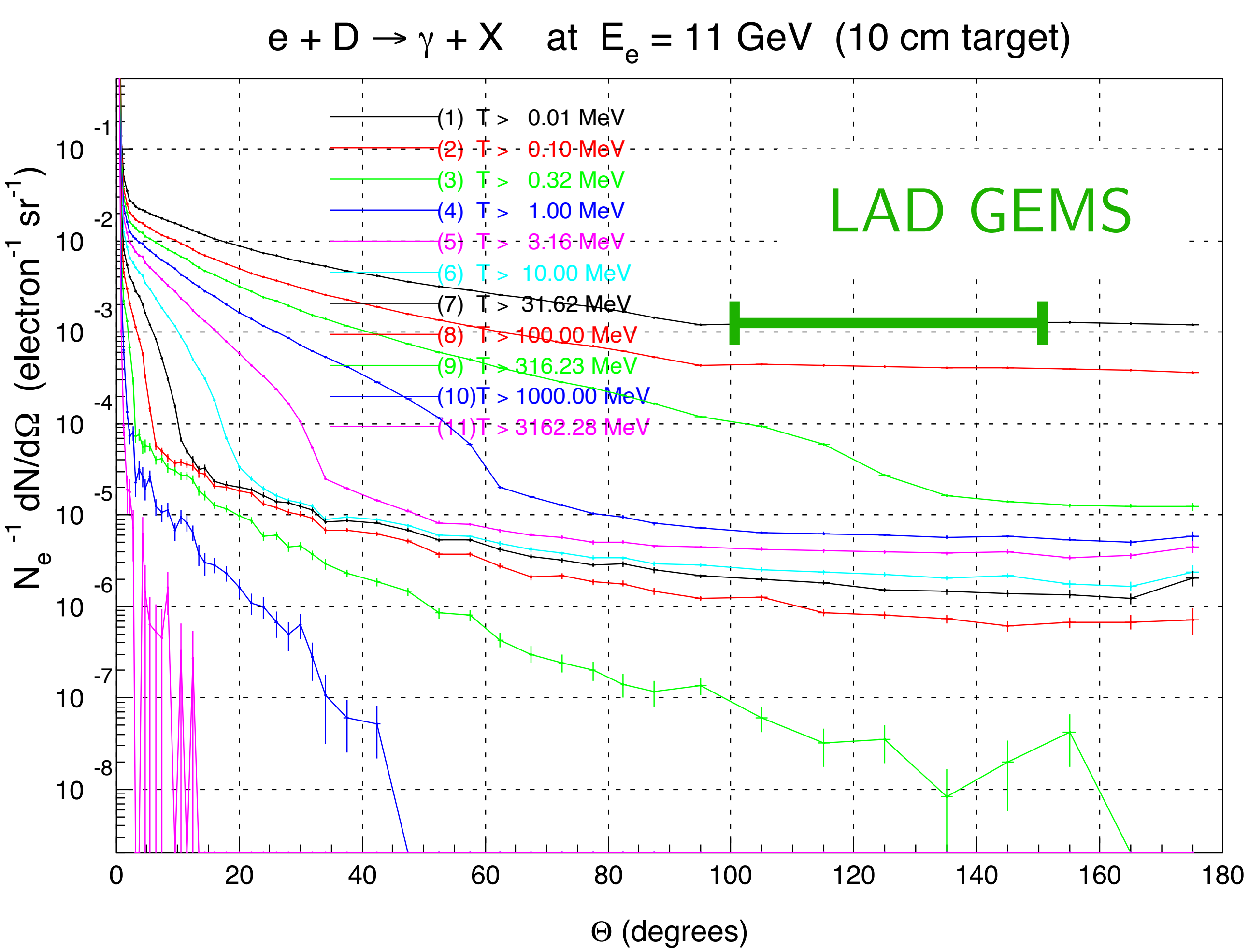
Background flux from target

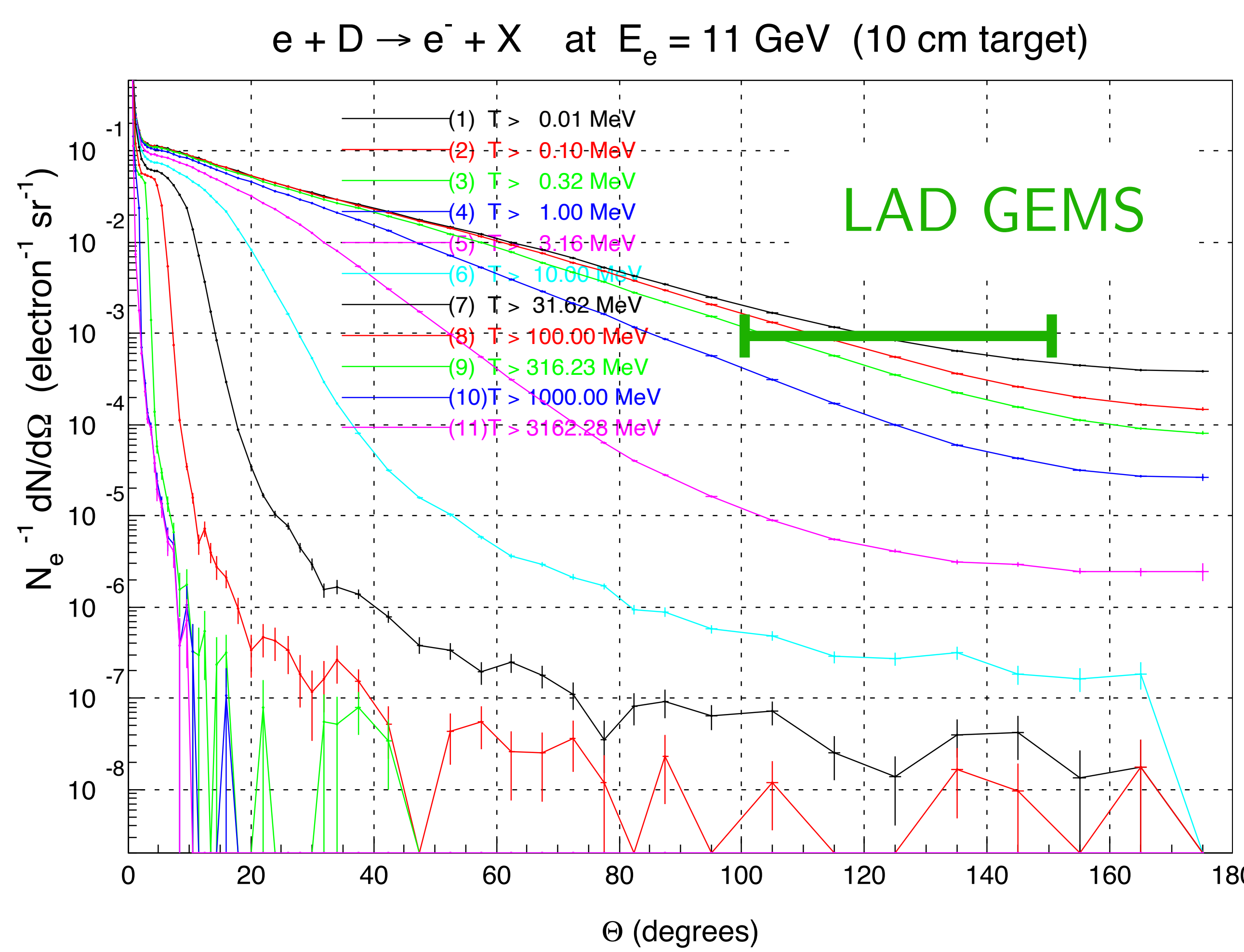
- GEANT4 simulation of 10.9 GeV electron beam on 20 cm LD2 target
- Custom physics list from PRad GEM simulations
- Include GMn GEM for photon rate comparison
- Simple sensitive-detector GEMs...no detector material or response



Background flux from target

- Photon rate at GMn GEM (90 kHz cm^{-2}) consistent with observed rate (100 kHz cm^{-2})
- Both photon and electron rates consistent with previous calculations by P. Degtiarenko (below)





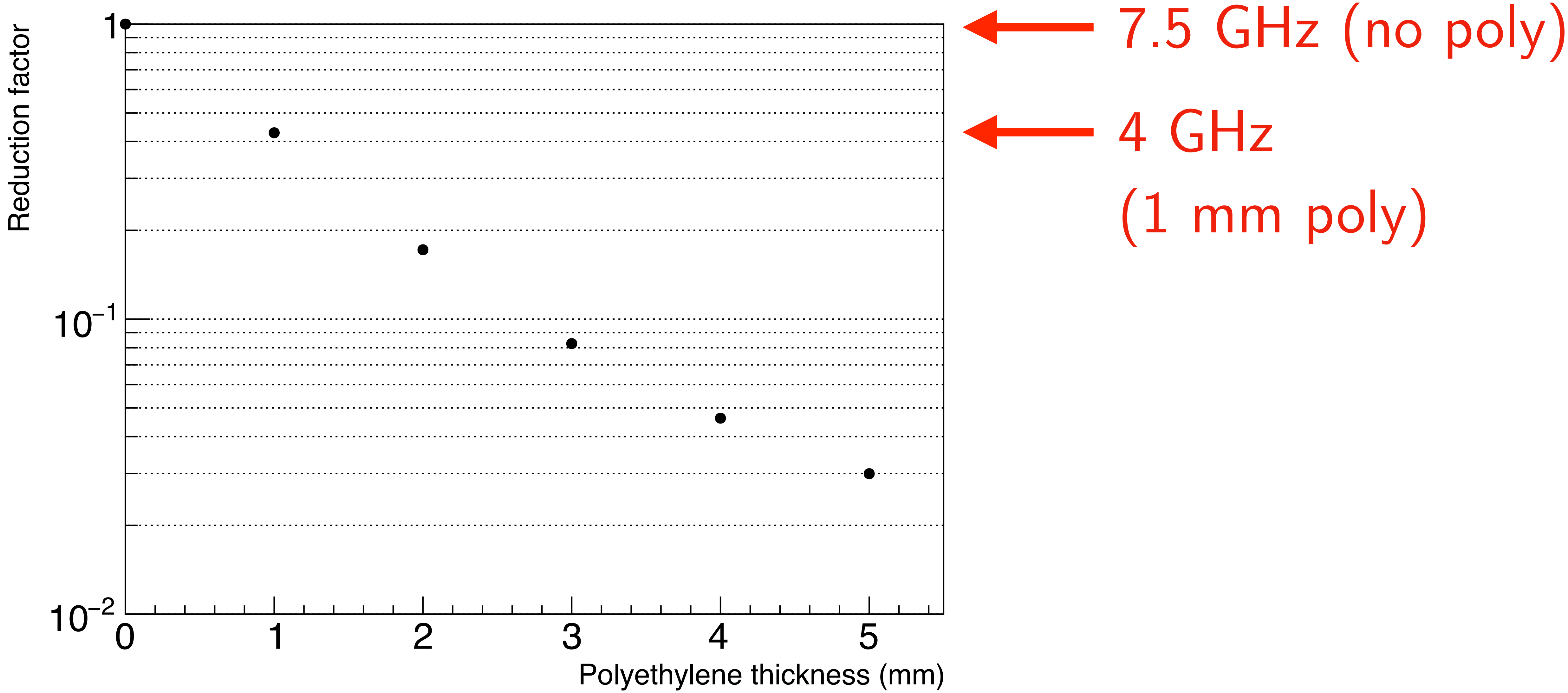
γ rate = 22.5 GHz

e^- rate = 15 GHz

Flux reaching GEM1

Material between target and GEMs

- 0.4 mm aluminum window
    - Reduces electrons rate from 15 GHz to 7.5 GHz (GEANT4)
- Optional: thin sheet of polyethylene before GEMs
    - Electron reduction vs. thickness shown below (from GEANT4)



Detection rate in GEMs

Detection efficiency of particles:

- 0.5% photon detection efficiency (from SBS ERR)
- 100% electron detection efficiency

Photons

(22.5 GHz) x (0.5%) = 0.1 GHz

Electrons (with 1 mm polyethylene)

(4 GHz) x (100%) = 4 GHz

4 GHz x 40 ns = 160 random hits

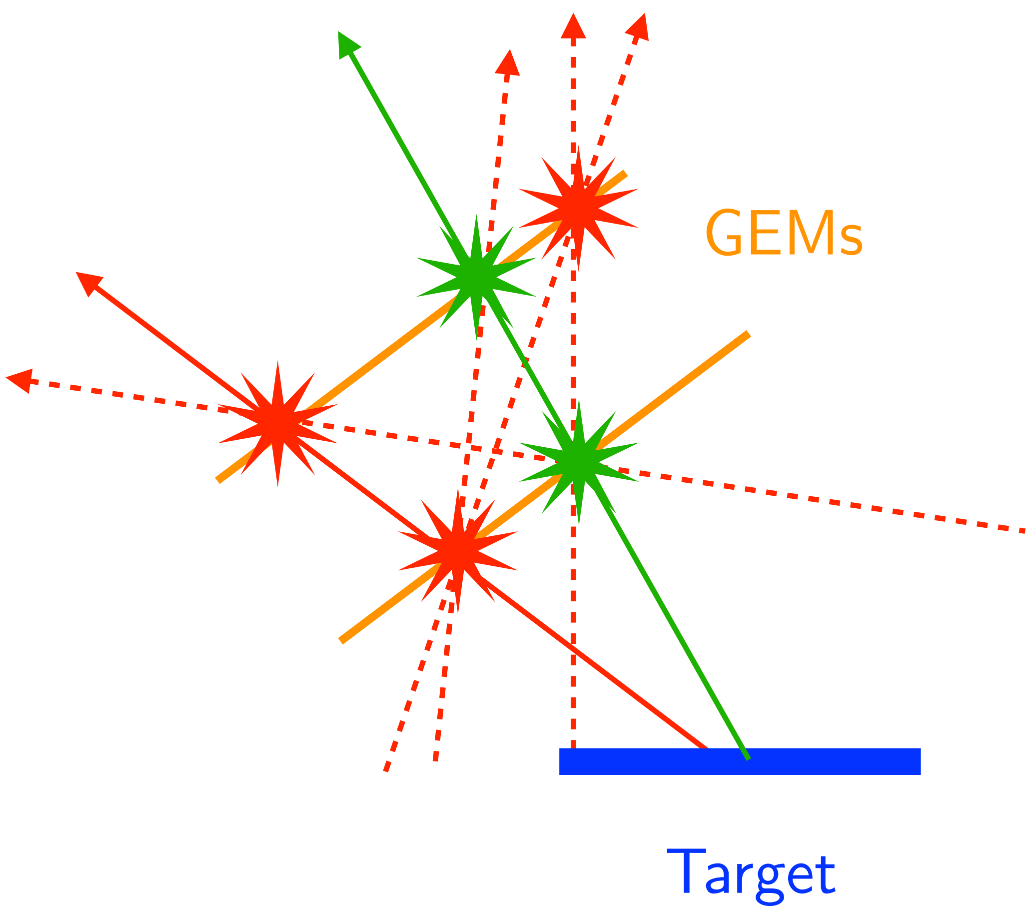
Round up to 200 *random hits/event*

Track multiplicity simulation

For each *desired event*, add...

- 1 accidental tracks
- 200 random hits in each GEM plane

Form tracks from *all* pairs of GEM hits



y-dimension (vertical) not pictured, but is included in simulation

Kinematic cuts

Use the *true* scattering kinematics to calculate Q^2, W^2, and x'.

For *all* events, require:

$$Q^2 > 2 \text{ GeV}^2$$
$$W^2 > 4 \text{ GeV}^2$$

Additionally, require:

$$0.25 < x' < 0.35$$

For low-x' kinematics

$$0.45 < x' < 0.55$$

For high-x' kinematics

Cuts to suppress background

For each event, we have:

- True target vertex position z_{vertex}, known from [S]HMS
- Hit positions at LAD

For every possible track...

- ...project to LAD
- ...project to target (get z_{track}, r_{track})

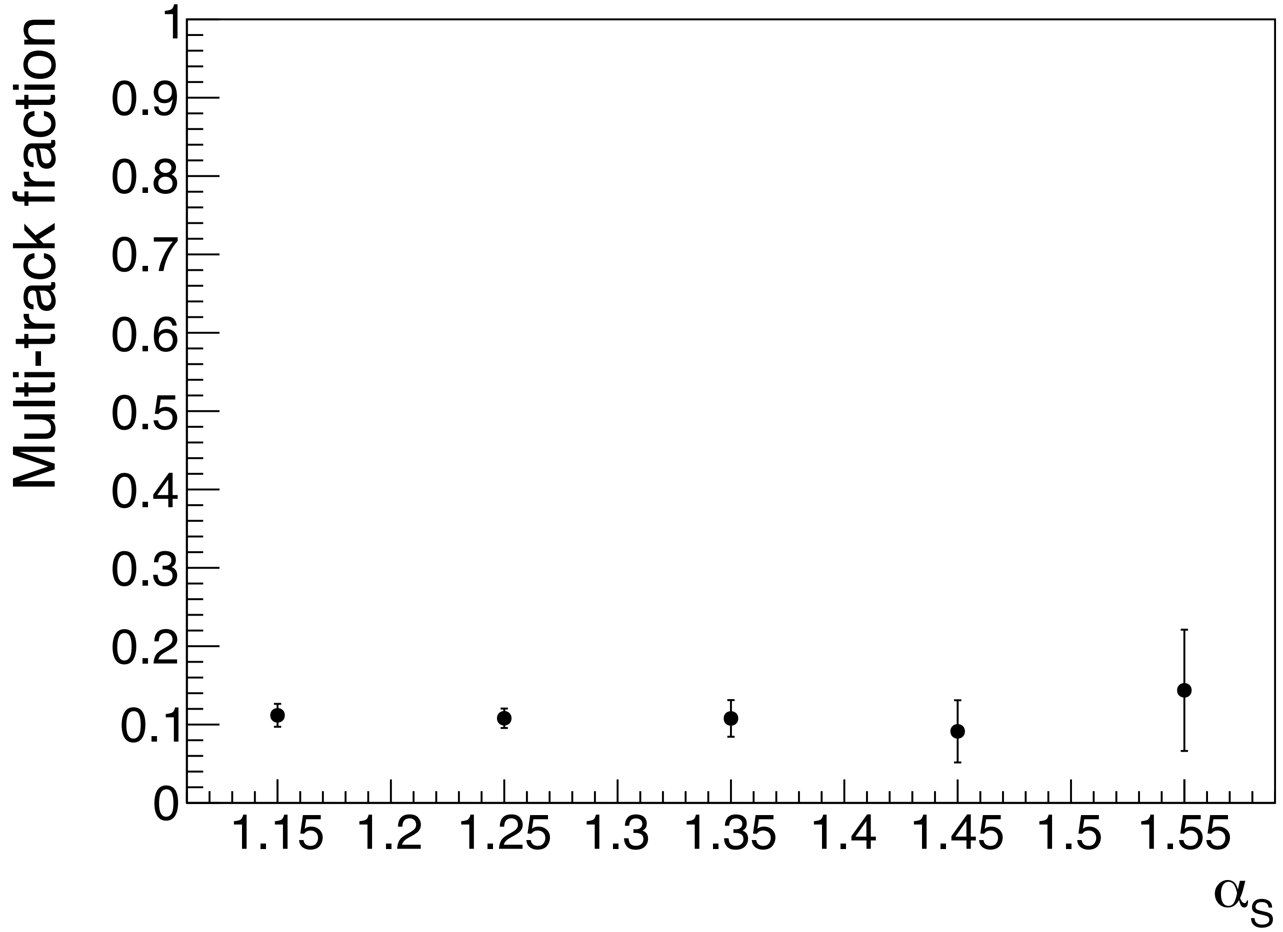
Cuts to suppress background

Reject tracks that don't satisfy:

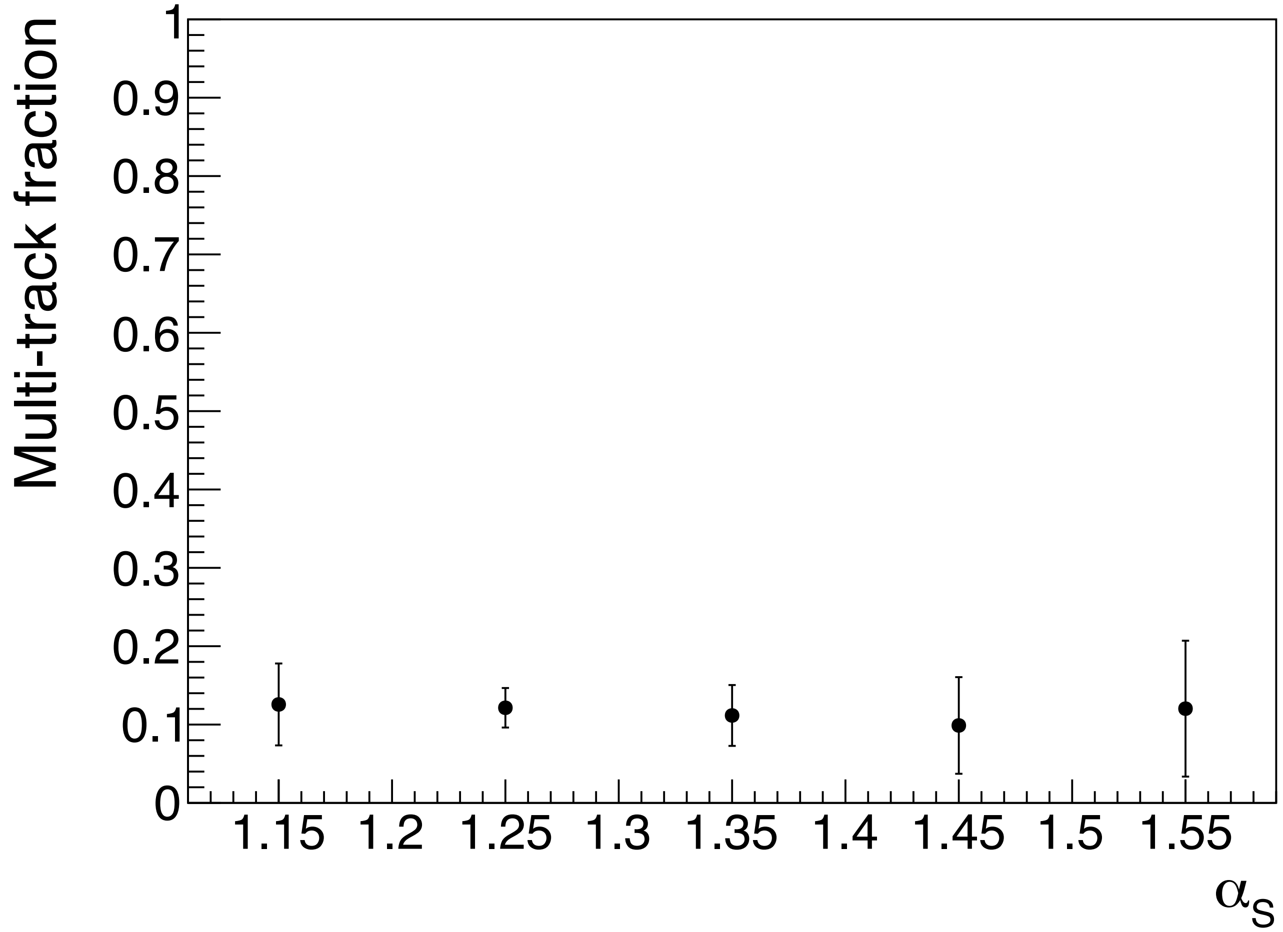
- $|\Delta z_{targ}| = |z_{track} - z_{vertex}| < 1$ cm
- $r_{track} < 1$ cm
- Projection to LAD intersects same plane and bar as LAD hit
- $|\Delta y_{LAD}| = |y_{track} - y_{LAD}| < 10$ cm
  (corresponds to 3σ time resolution of 450 ps)

Out of > 40000 possible tracks, few survive tracking cuts

Low x'



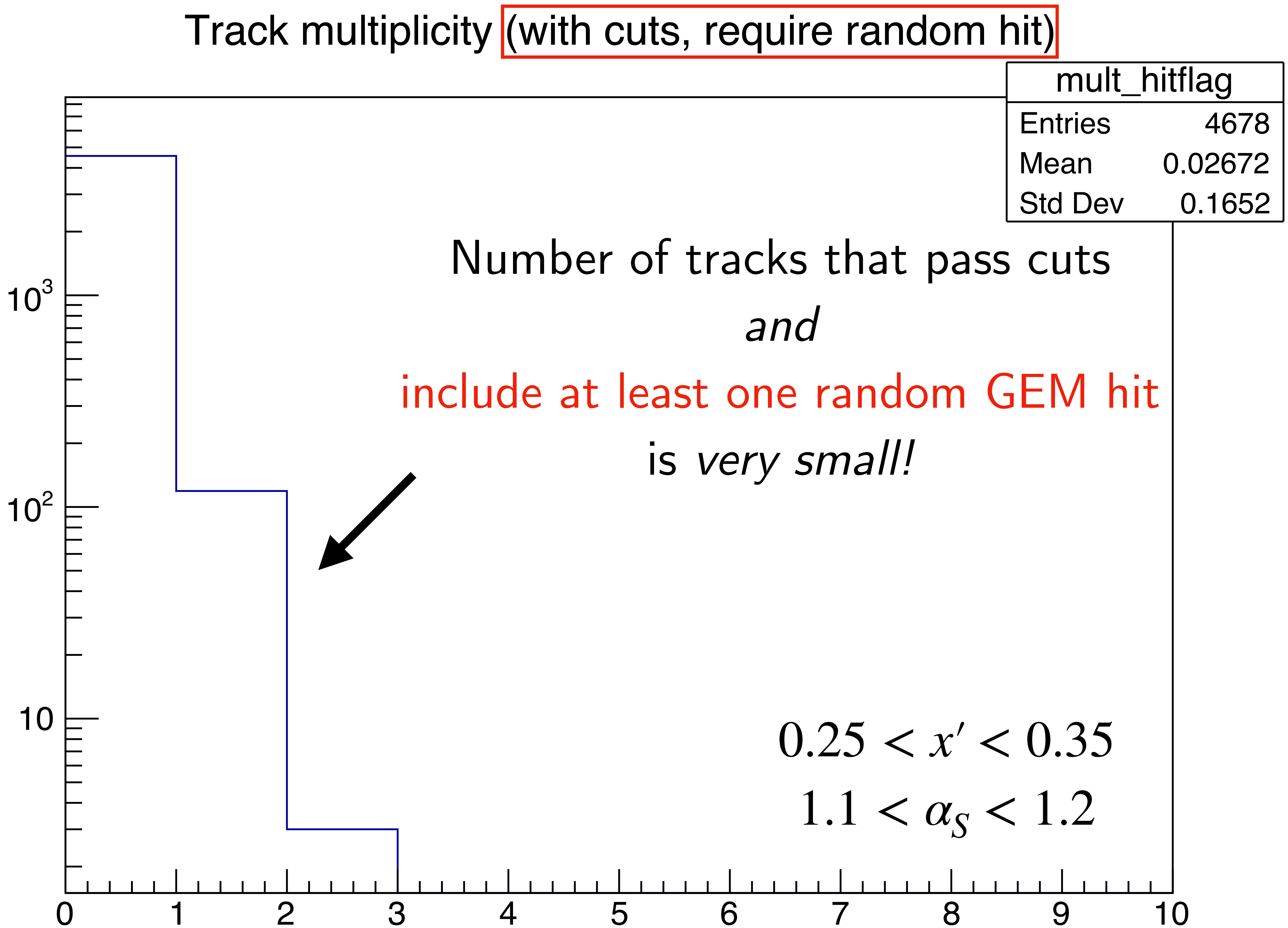
High x'



$\sim$90% of events have 1 track

$\sim$10% of events have 2+ tracks

Majority of spurious tracks come from accidental tracks, not random hits



Summary

- GEANT4 simulations give expected random background rate in GEMs of up to 10 GHz
- This rate is dominated by electrons, which can be reduced with a thin (< 5 mm) sheet of polyethylene
- Track simulation indicates that random background rates up to 5 GHz are manageable for LAD GEM vertexing:
  - $\sim$90% of events have single track meeting tracking cuts
  - $\sim$10% of events have > 1 tracks meeting tracking cuts