Particle identification (e/hadron separation) with transition radiation tracking

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Electron Identification

- Improve identification of scattered electron
- Identification of secondary electrons (decay products)
- Reject background

- A typical e/π rejection factor of EMCAL is ~50 (150)
- EMCAL + HCAL
- π0 -> γ γ
  (in EMCAL signal equal to e)
- γ-> e+e-

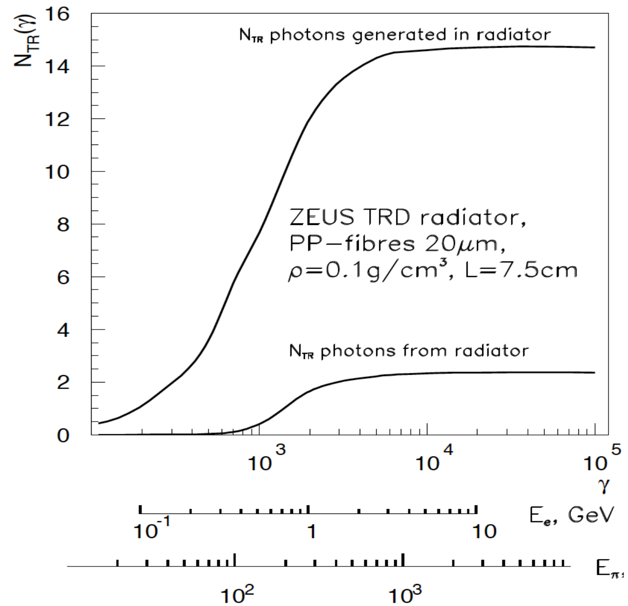
- Background enviroment:
  - High multiplicity, large number of charged hadrons.
  - Large π^0 background.
- Need: A tracker combined with TRD/PID function: which could provide additional e/hadron rejection 10-100 and will cover energy range 1-100 GeV =>

Transition Radiation Detector + Tracker (TRD/T)

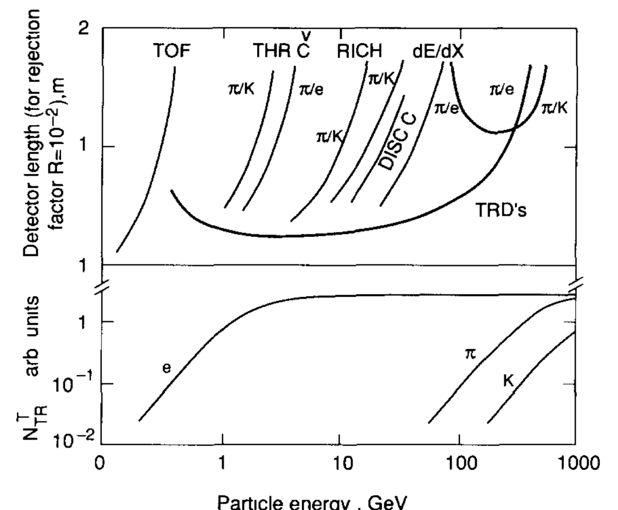
Why transition radiation detector?

J.Tandler

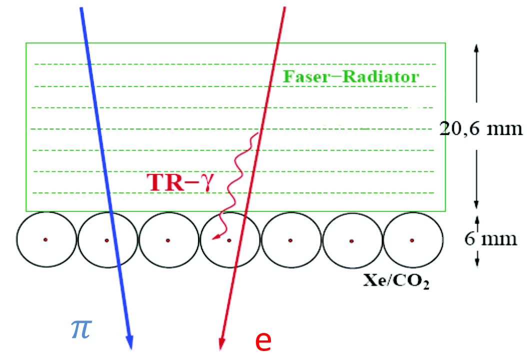
- TRD separate particles by their gamma factor
- e/π separation in high $\gamma = E/m$ region (1-100 GeV) where all other methods are not working anymore.
- Provide high rejection factor for a small detector length in a wide range of a particle momentum.
- Identification of the charged particle "on the flight": without scattering, deceleration or absorption.
- Typically TRD is either combined with tracking detector (ATLAS TRT) or provide additional tracking information in the region between RICH and CAL(HERA-B).



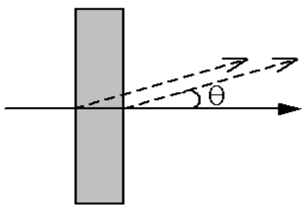
Length of detector for rejection factor 100.



Brief introduction to Transition Radiation



- Transition radiation is produced by a charged particles when they cross the interface of two media of different dielectric constants



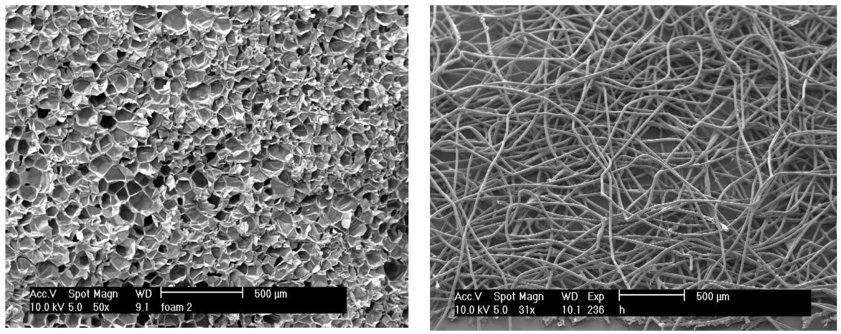
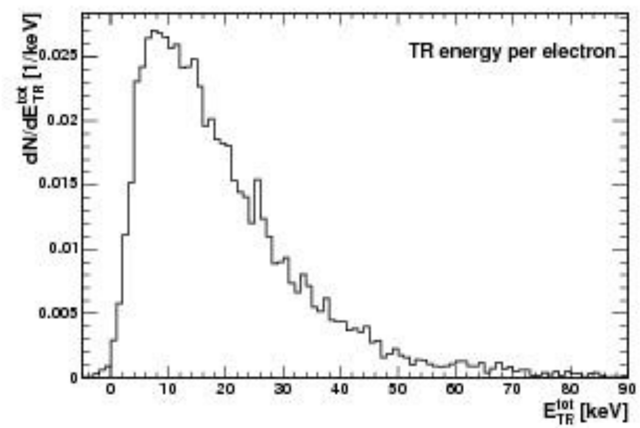
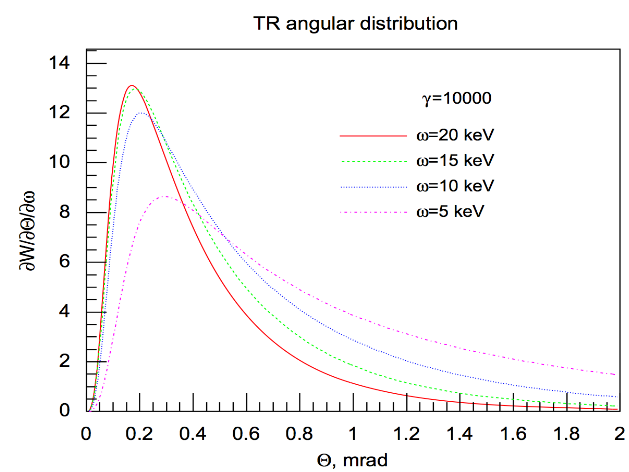


Figure 2: Electron microscope images of a polymethacrylimide foam (Rohacell HF71)(left) and a typical polypropylene fiber radiator (average diameter ≈ 25 μm) (right) [52].



- the probability to emit one TR photon per boundary is of order α~1/137. Therefore multilayer dielectric radiators are used to increase the transition radiation yield, typically few hundreds of mylar foils.
- Energy of TR photons are in X-ray region (2 - 40 keV)
- Total TR Energy ETR is proportional to the γ factor of the charged particle
- TR in X-ray region is extremely forward peaked within an angle of 1/γ



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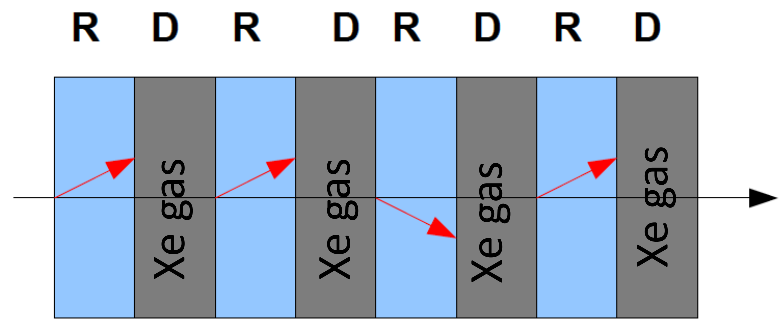
How easy is it to detect Transition Radiation ?



- Stack of radiators and detectors (sandwich)

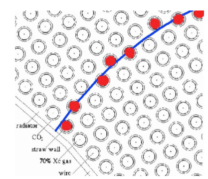
- For “classical” TRD (straws, MWPC)
  gas with high Z is required for better absorption of TR photons: Xenon gas (Z=54)

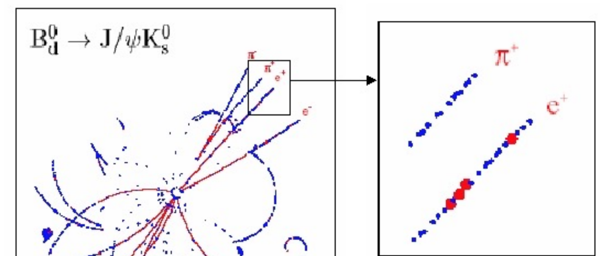
- TRDs are not "hadron-blind" ! they see all charged particles dE/dx

- Several methods exist to identify TR photons on the top of dE/dx:
  (TR photons (5-30 keV) over a dE/dX background in Xe gas (2-3 keV)).

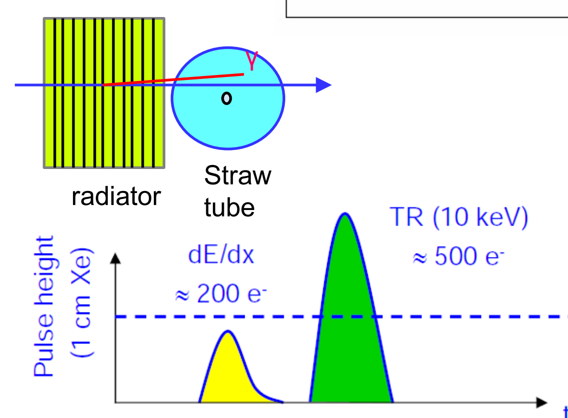
> - **Discrimination by threshold** (ATLAS)
> - ***Average pulse height along adjacent pads (or along a track)*** (ALICE) => (next slide)

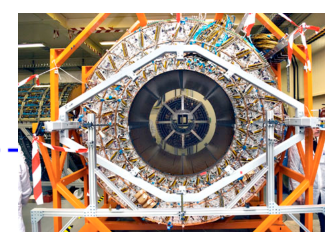
ATLAS TRT





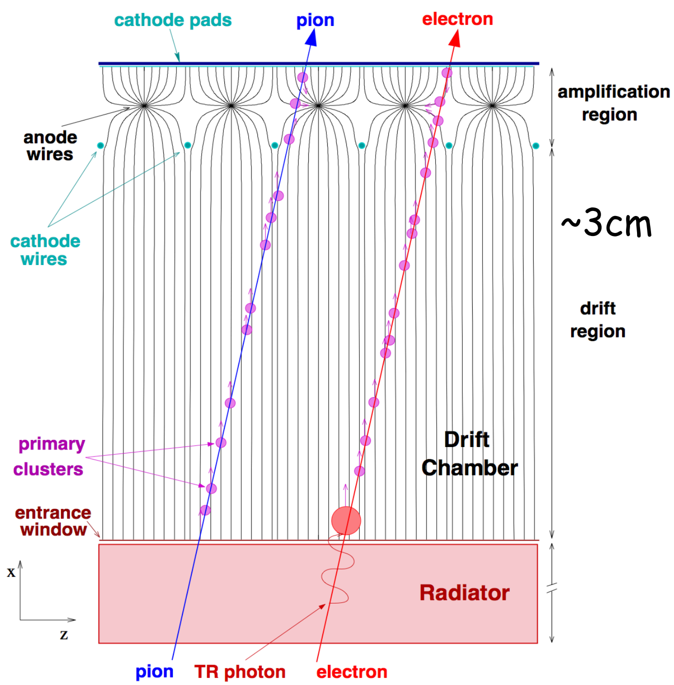
Simulated event, illustration of clusters from eletron/positron and pion hits – small blue dots are ionizing hits, large red dots are TR hits



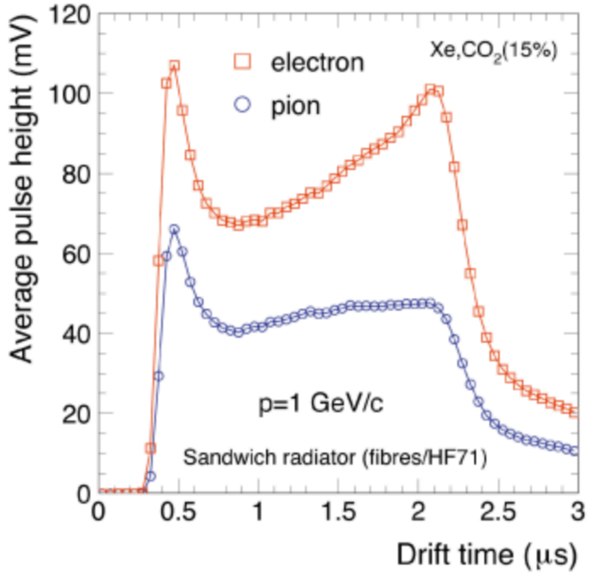


TR detection in MWPC, Silicon

- With a MWPC:
For electrons - significant increase in the average pulse height at later drift times, due to the absorption of the transition radiation near the entrance of the drift chamber.



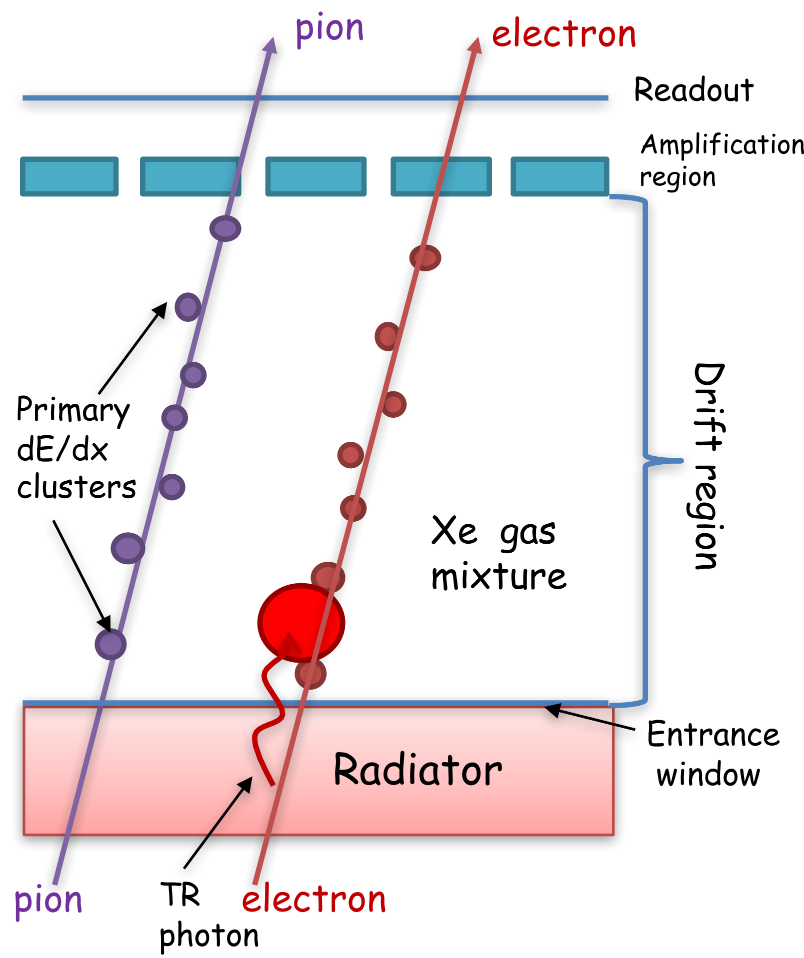
ALICE MWPC - TRD



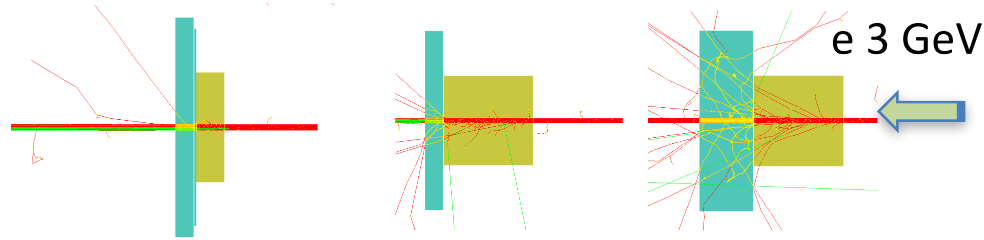
GEM as Transition Radiation detector and tracker for EIC

eRD22
EIC R&D
program

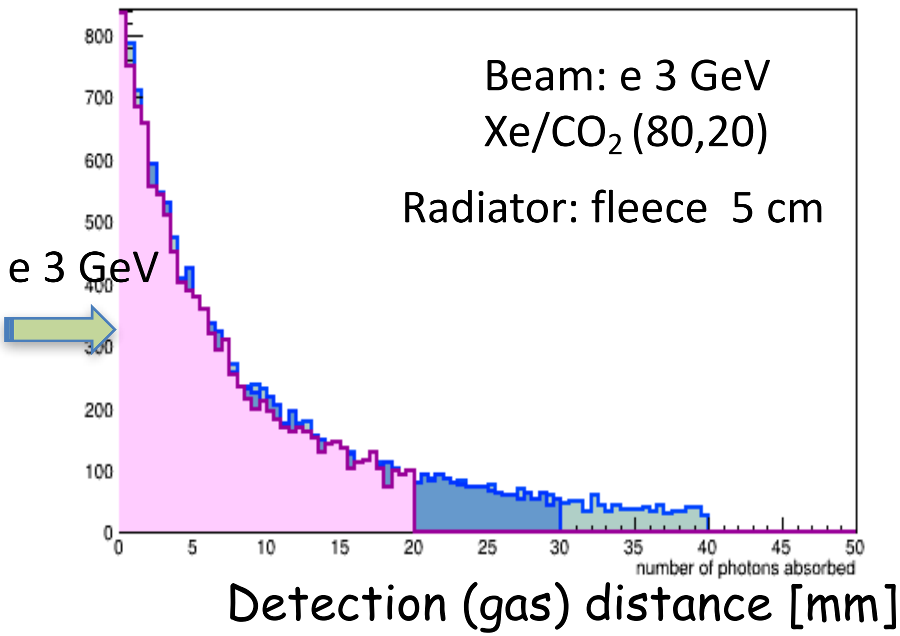
- High resolution tracker.
- Low material budget detector
- How to convert GEM tracker to TRD:
  - ✓ Change gas mixture from Argon to Xenon (TRD uses a heavy gas for efficient absorption of X-rays)
  - ✓ Add a radiator in the front of each chamber (radiator thickness ~5-10cm)
  - ✓ Increase drift region up to 2-3 cm (for the same reason).
  - ✓ Number of layers depends on needs: Single layer could provide e/pi rejection at level of 10 with a reasonable electron efficiency.



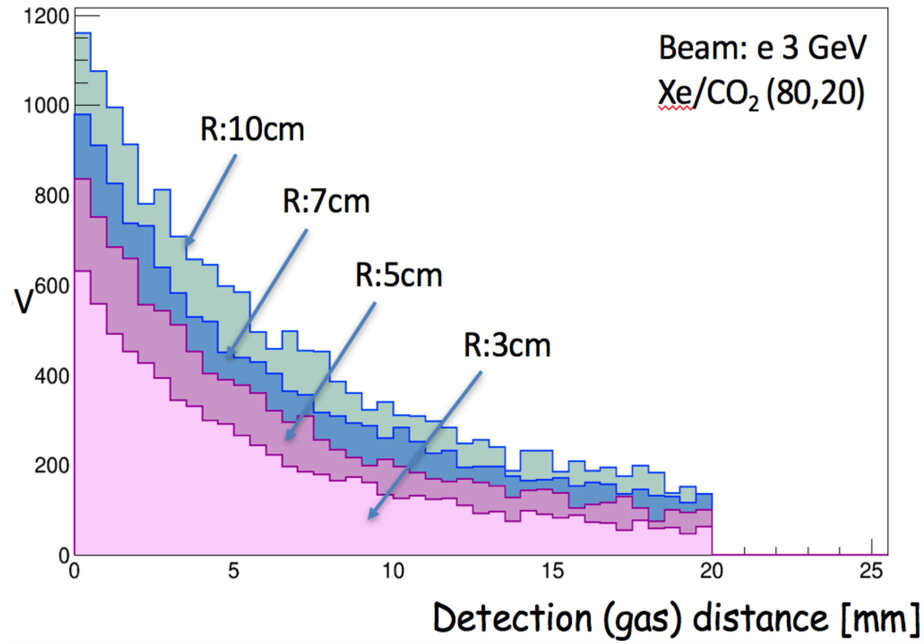
GEANT4 simulation



Energy deposition from TR photons along the track

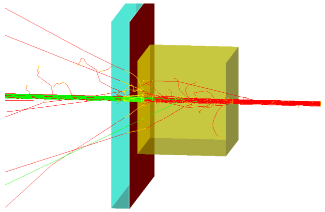


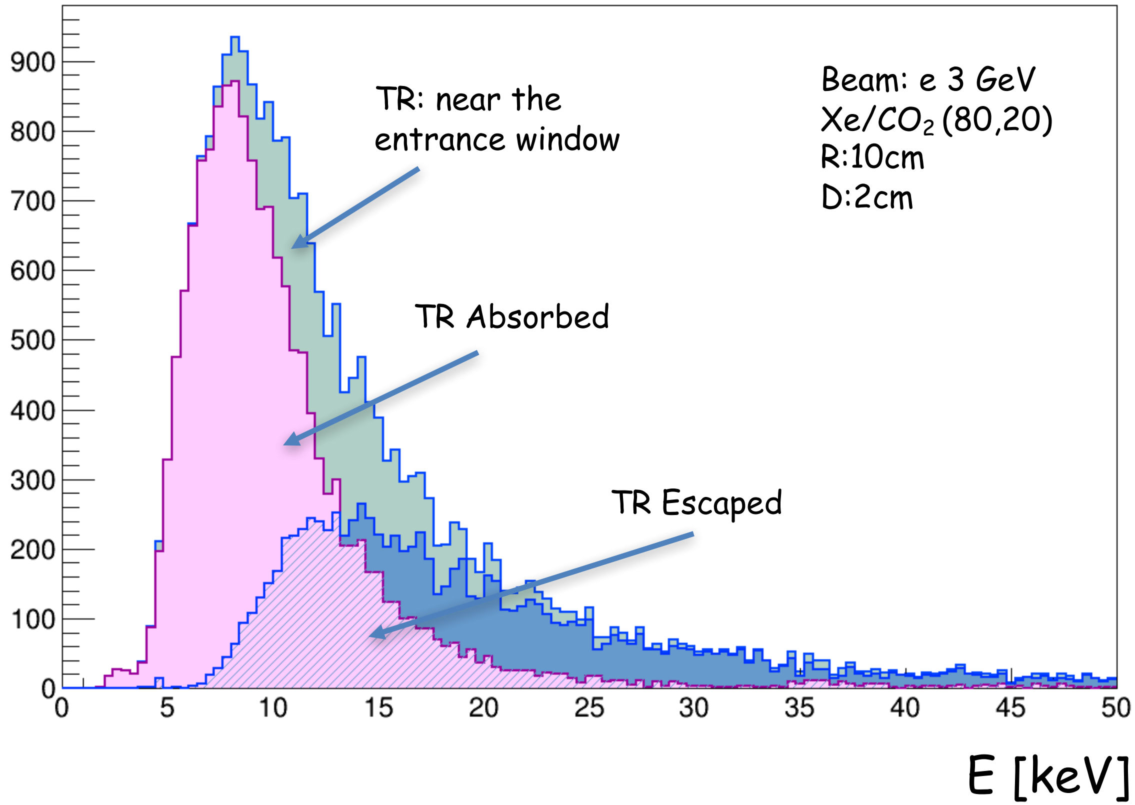
Energy deposition from TR photons along the track



- TR-photons mostly absorbed close to the entrance window.
- Increase of a radiator material helps to increase TR-photon yield.

Energy spectrum of TR photons

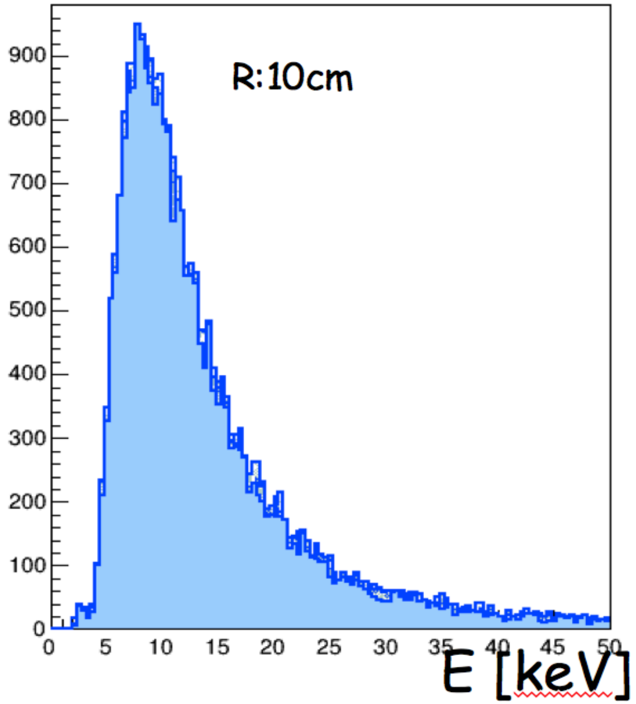




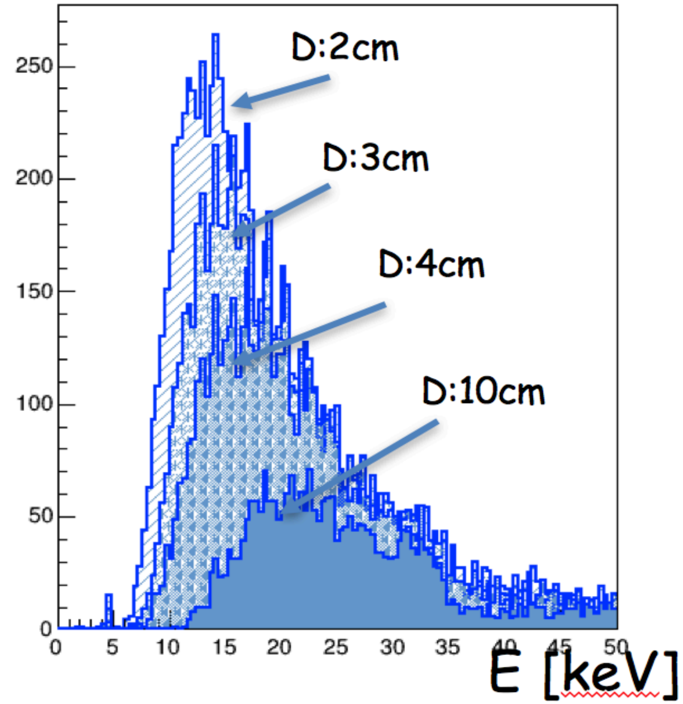
- Most energetic part of TR spectrum escapes detection.

Energy spectrum & yield (fixed radiator volume)

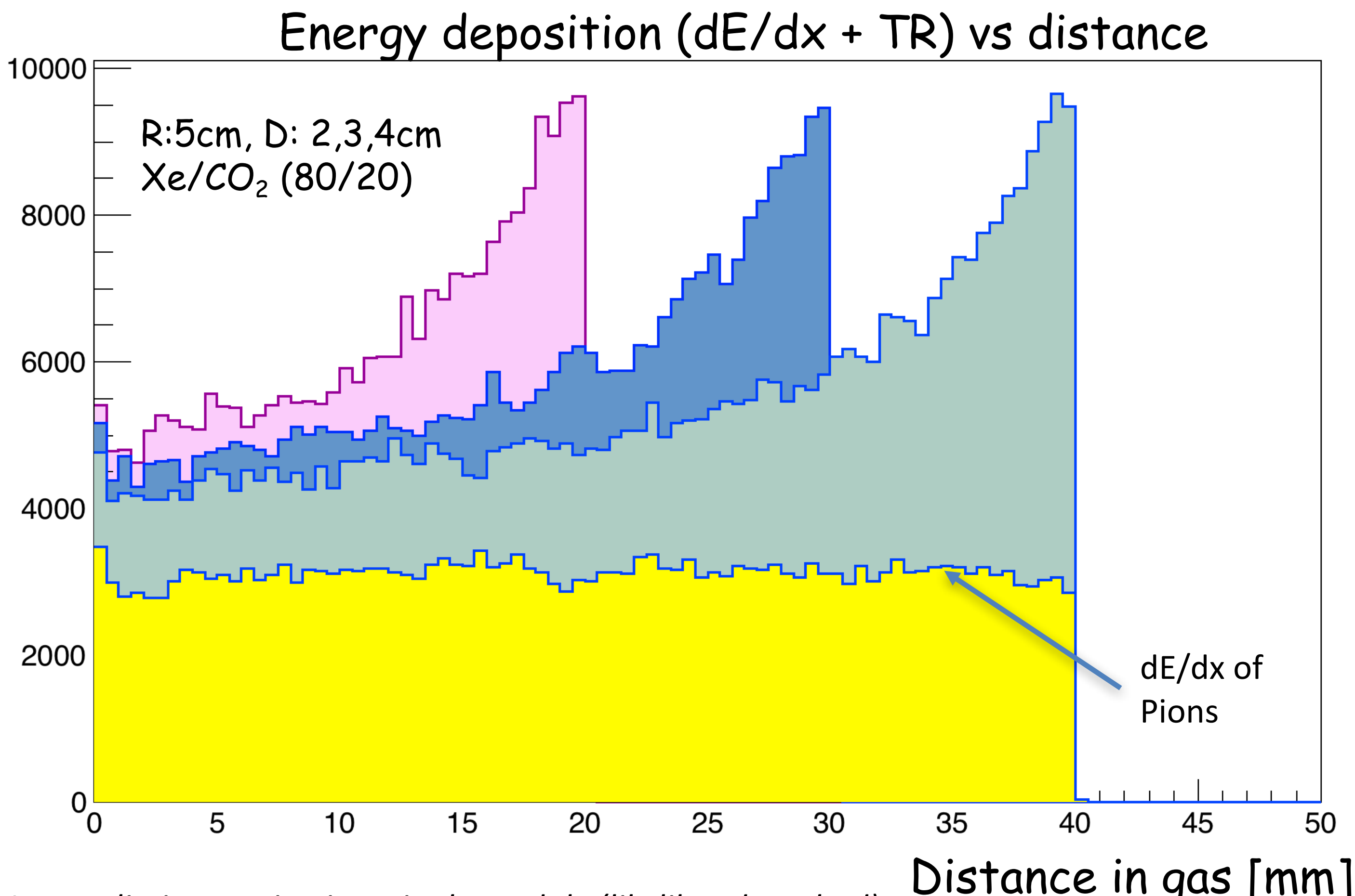
TR: near the entrance window



TR: Escaped detection



GEANT4: electron and pion comparison

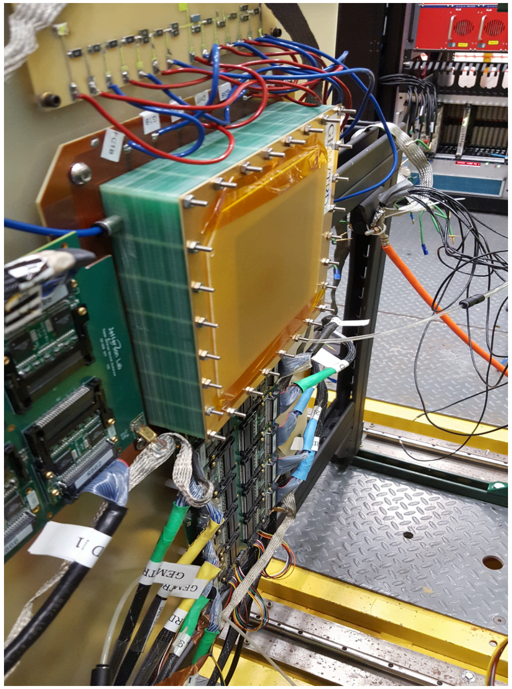


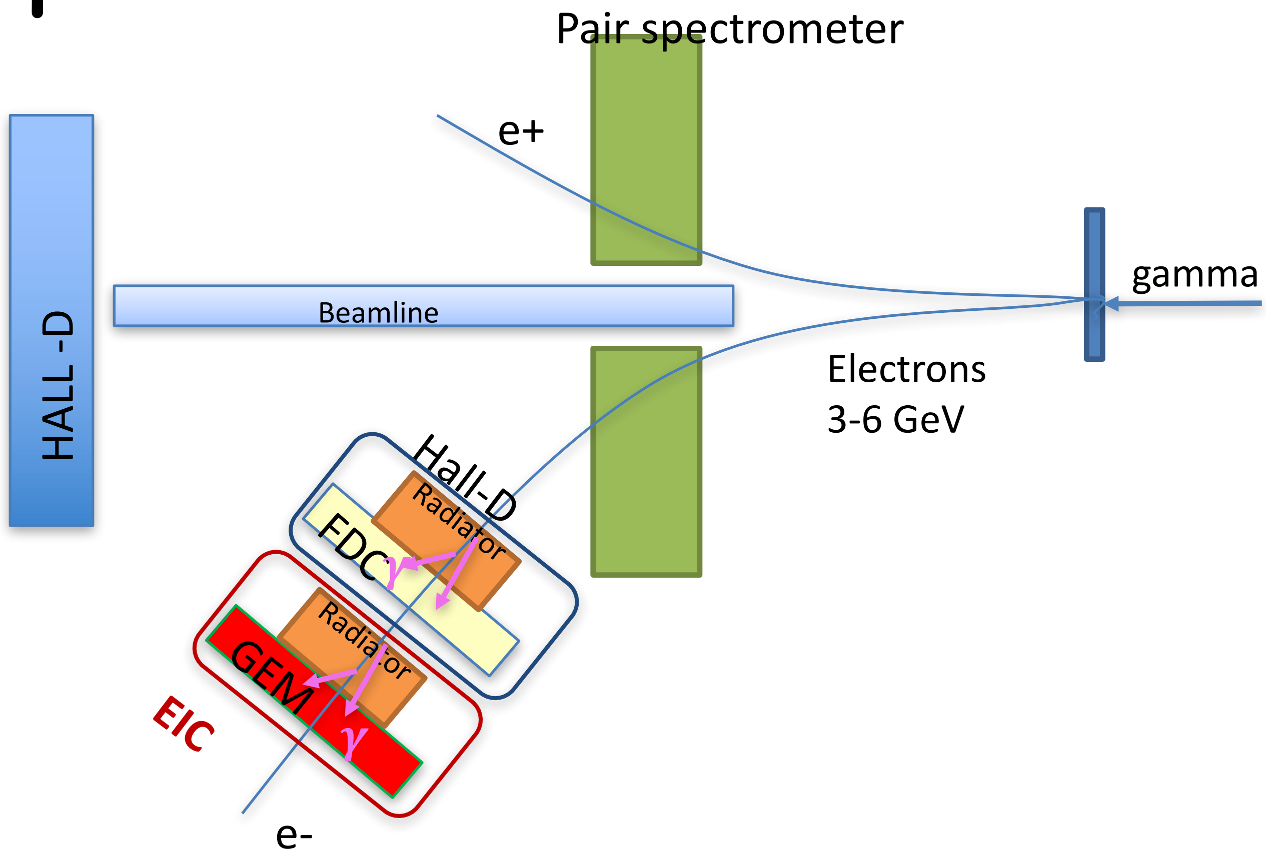
e,π ~3 GeV

Very preliminary rejection, single module (likelihood method)

	90% eff	**70% eff**
2cm Xe	2.5	12
4cm Xe	4.5	17

Test Setup at JLAB HALL-D

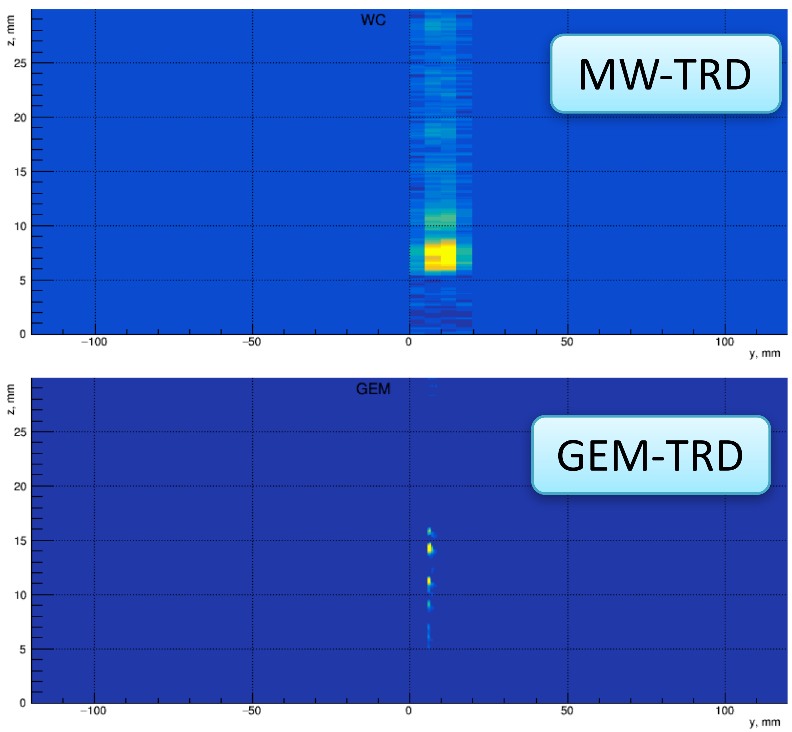


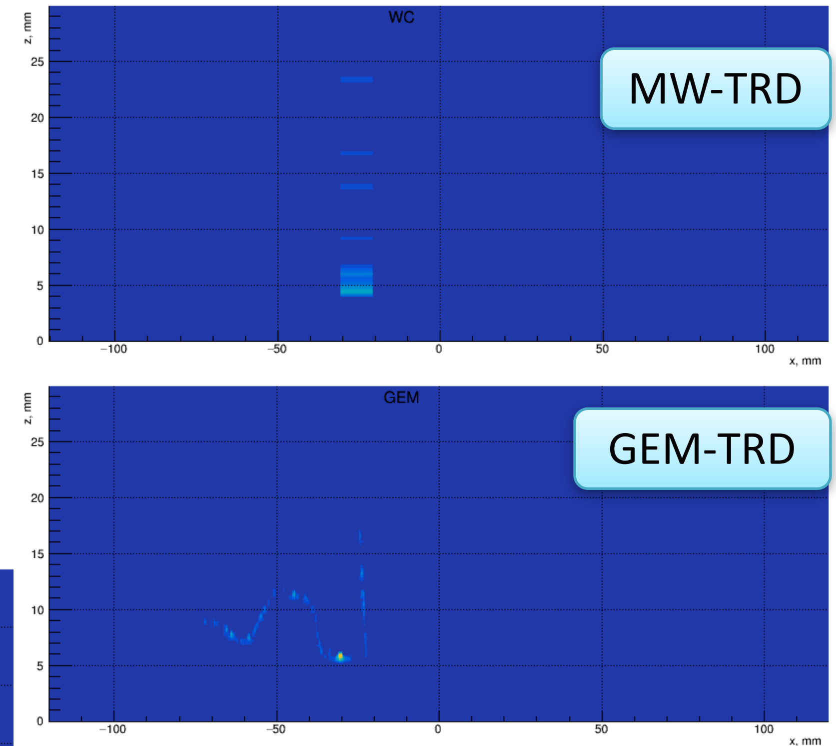


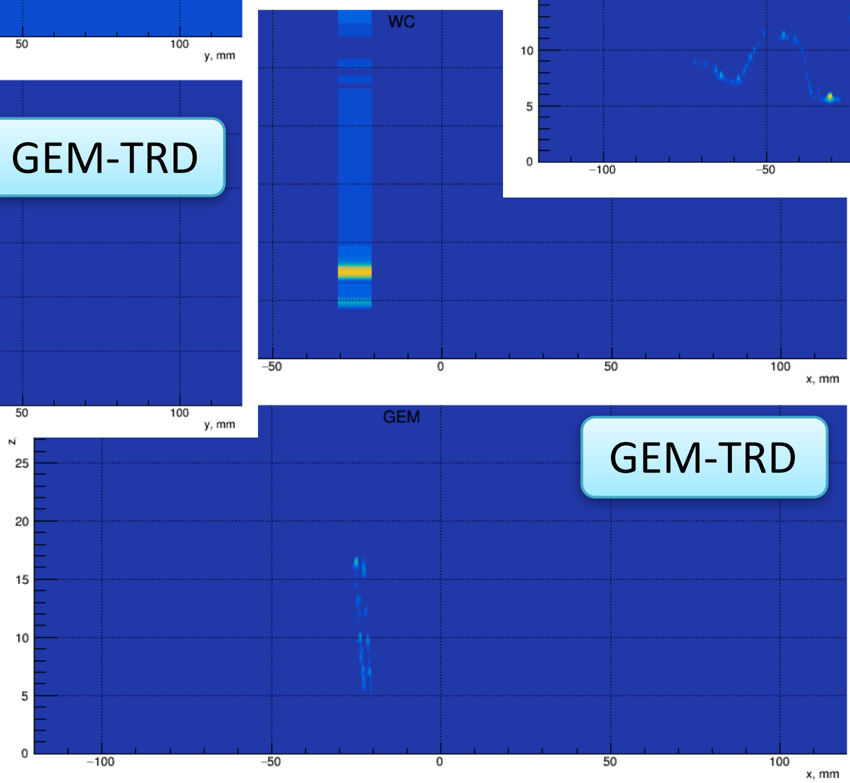
- 3-6 GeV electrons in Hall-D from pair spectrometer
- In parallel with Hall-D MW-TRD system
- Ongoing measurements

eRD22
EIC R&D
program

GEM-TRD







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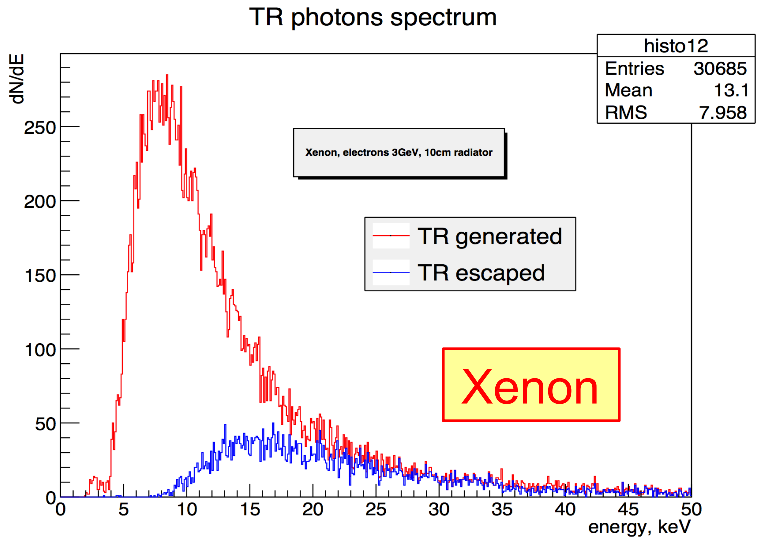
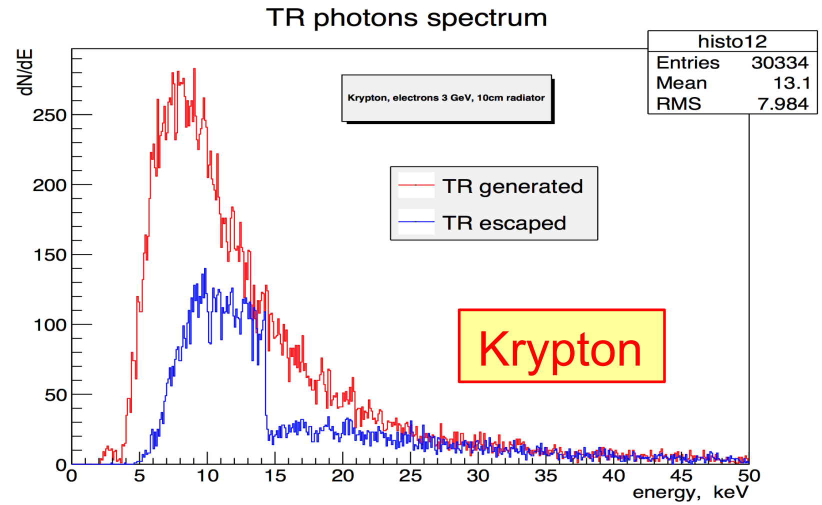
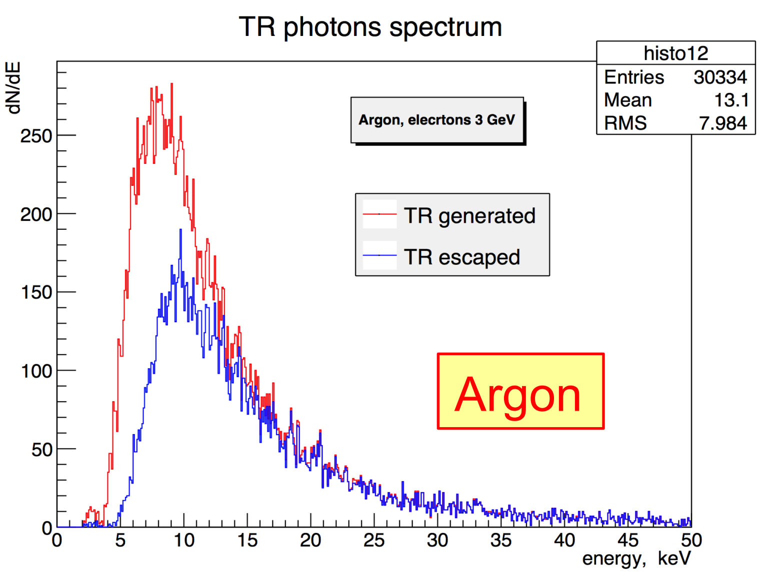
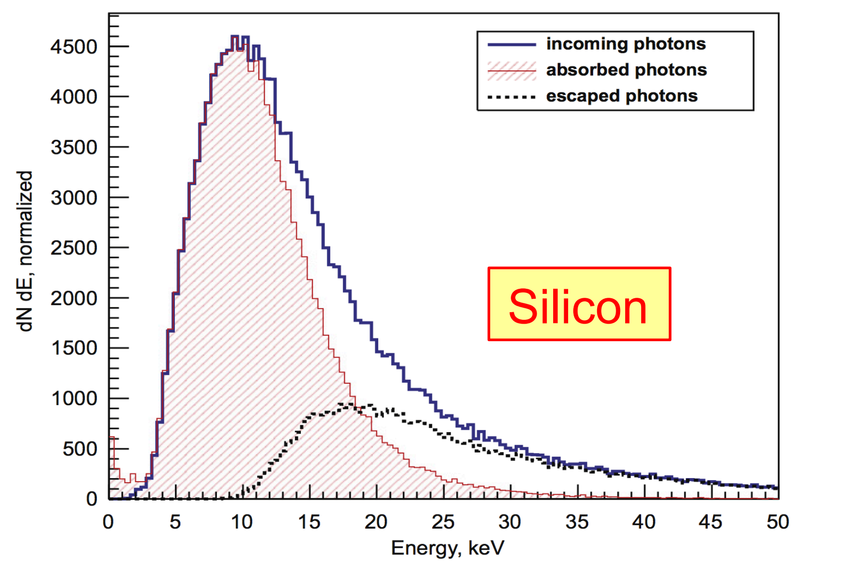
Alternative to Xe ??







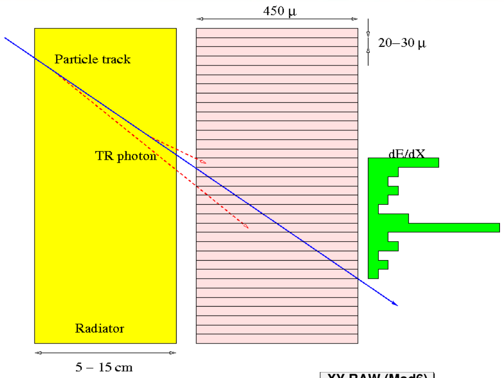


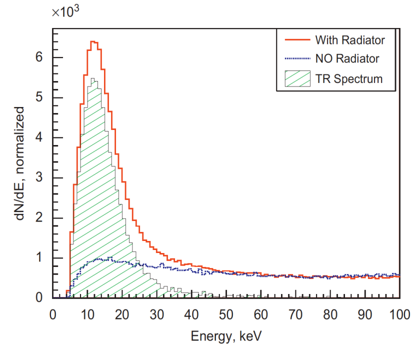
Silicon TRD

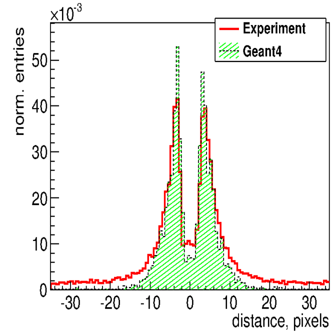
<u>Gas:</u> in Xe dE/dx ~2-3 keV
<u>Problem:</u> A huge dE/dX of particles in 300-700µm of silicon - about 100-300keV (TR photons 4-40 keV).

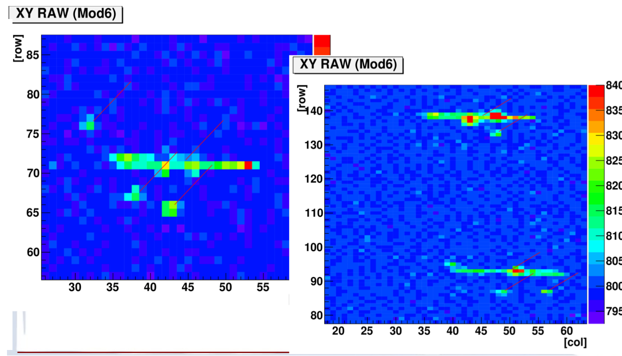
- **DEPFET silicon pixel detector**
  - Low noise, high S/N with 450 µm thick fully depleted bulk (sensitive area), pixel size – 20x20µm^2 .
  - TR photons are clearly visible and separated from track by a few pixels!

"New transition radiation detection technique based on DEPFET silicon pixel matrices", J.Furletova, S. Furletov, NIM-A 2010, http://dx.doi.org/10.1016/j.nima.2010.06.342
"Geant4 simulation of transition radiation detector based on DEPFET silicon pixel matrices", J. Furletova,S. Furletov, DOI: 10.1016/j.nima.2012.05.009



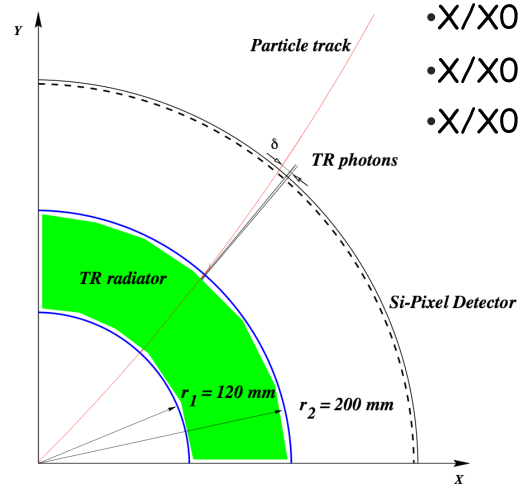






- **Separation of TR and dE/dX in different pixels in magnetic field**

2000 B. Dolgoshein proposed a design for ILC/TESLA detector (see proposal LC-DET-2000-038)



- X/X0 ~0.2 % for 4cm of Xe
- X/X0 ~ 1.5% for 10 cm of radiator
- X/X0 ~ 1.5% for 600µm Si

Radiators

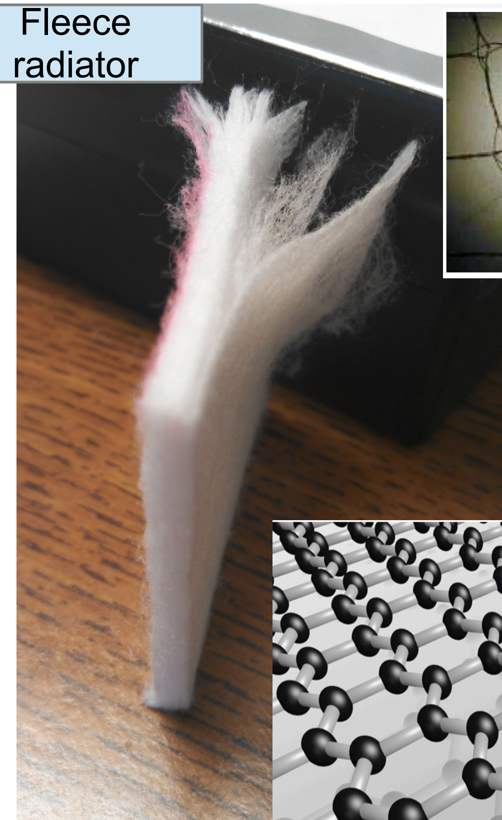
- The theory of transition radiation predicts that the best radiator is a stack of regular foils:

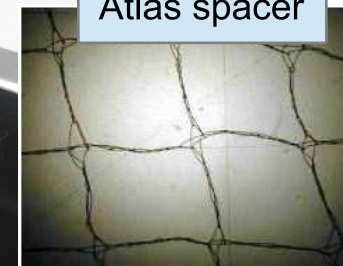
  20-30μ mylar foils and 200-300μ air gap.

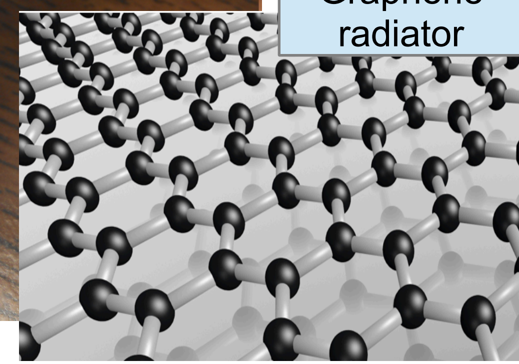
- ATLAS uses foils and spacer between foils to provide air gap.
- ZEUS and many other experiments used fleece radiator
- Proposals to use Graphene radiator: (?)

  "Measuring the Lorentz factors of energetic particles with transition radiation", M.Cherry, 10.1016/j.nima.2012.05.008

- R&D on new







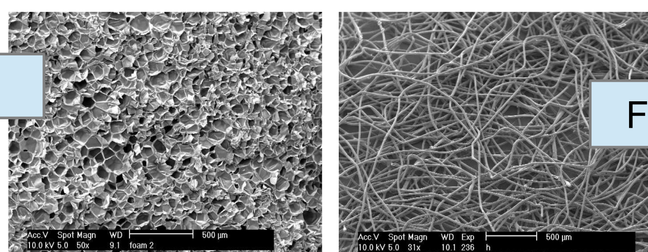
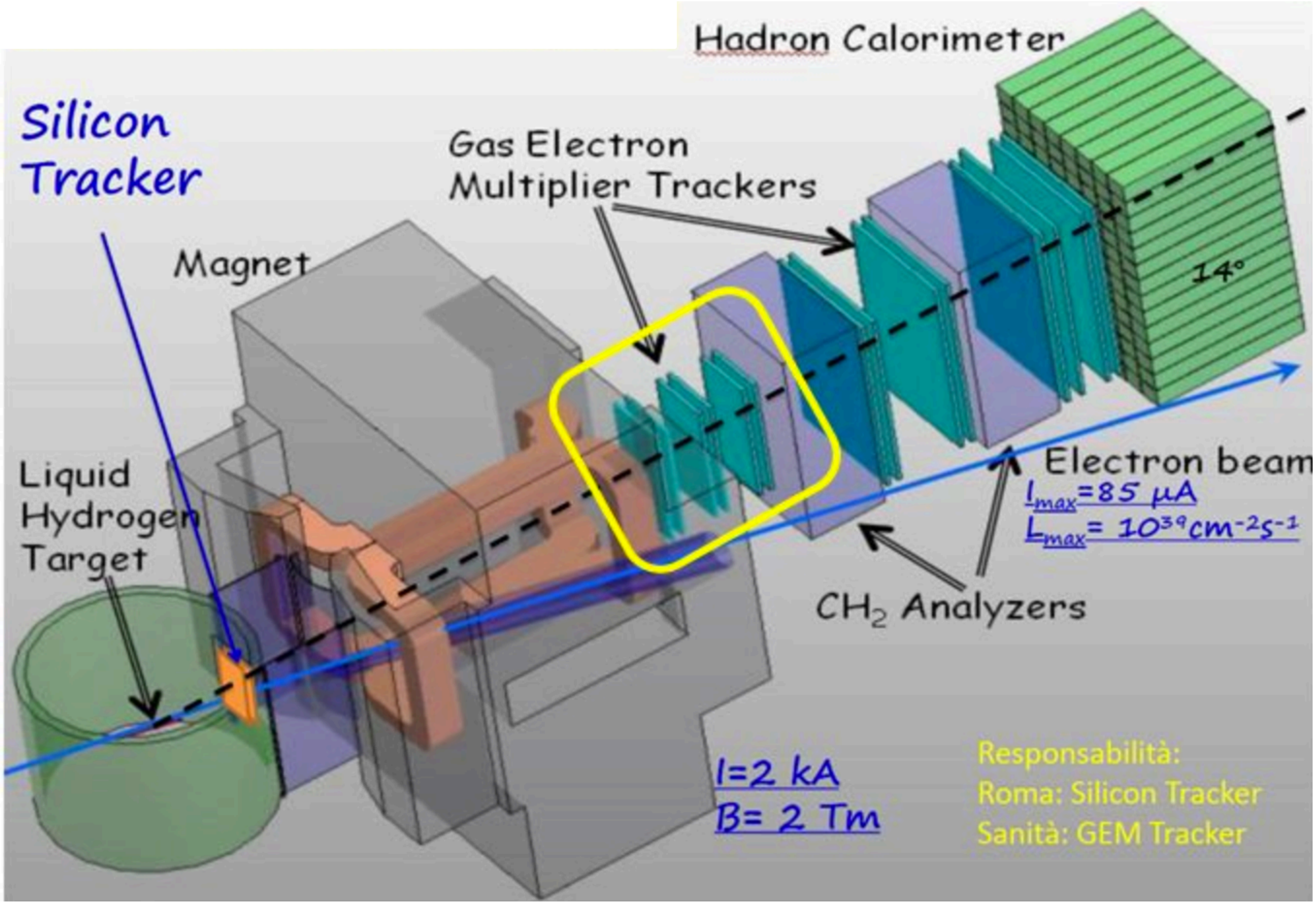


Figure 2: Electron microscope images of a polymethacrylimide foam (Rohacell HF71)(left) and a typical polypropylene fiber radiator (average diameter ≈ 25 μm) (right) [52].

GEM at HALL-A


Hadron Calorimeter
Silicon Tracker
Gas Electron Multiplier Trackers
Magnet
14°
Liquid Hydrogen Target
Electron beam
I_{max}=85 μA
L_{max}= $10^{39}cm^{-2}s^{-1}$
CH_2 Analyzers
I=2 kA
B= 2 Tm
Responsabilità:
Roma: Silicon Tracker
Sanità: GEM Tracker

Summary

- Electron identification and hadron background suppression are very important for any physics program
- High granularity tracker combined with TRD functionality could provide additional electron identification.
- Novel detector technology - GEM-TRD/T

Thank you!

Backup