eRD22: GEM based Transition radiation detector/tracker for EIC

Yulia Furletova (JLAB) on behalf of GEM-TRD/T working group

U.S. DEPARTMENT OF ENERGY JSA Jefferson Lab

GEM-TRD/T TEAM:

- Jefferson Lab:
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- University of Virginia
  - ✓ Kondo Gnanvo
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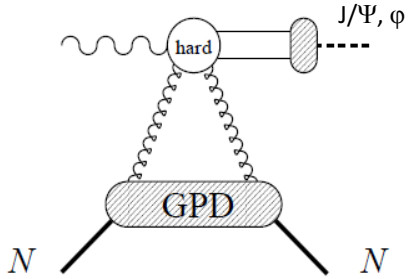
- Temple University
  - ✓ Matt Posik
  - ✓ Bernd Surrow

OUTLINE:

- Introduction
- GEANT4 simulation
- Test beam setup
- Summary and plans

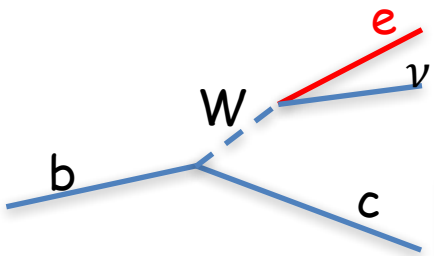
Electron identification at EIC

- **J/ψ** (Spatial gluon distribution from photoproduction and DVCS, saturation)
- **Heavy quarks** (Charm, beauty)
- **Spectroscopy** (XYZ)
- **Beyond the Standard Model**



Br (J/ψ->e+e-) ~6%

Br (J/ψ->μ+μ-) ~6%



Br ($B^{\pm}$->e+ν+X_c) ~10%

Br (D+ -> e + X) ~16%
Br (D0 -> e + X) ~ 6.5%

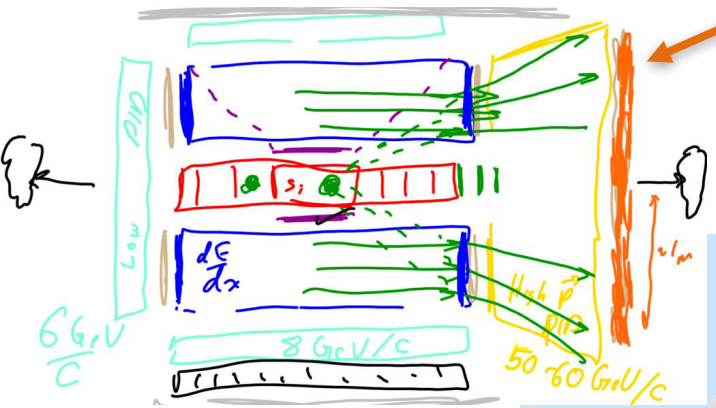
Environment:

- Background: High multiplicity, large number of charged hadrons.
- Large π^0 background.
- Electrons from particle decays will be boosted towards hadron end-cap

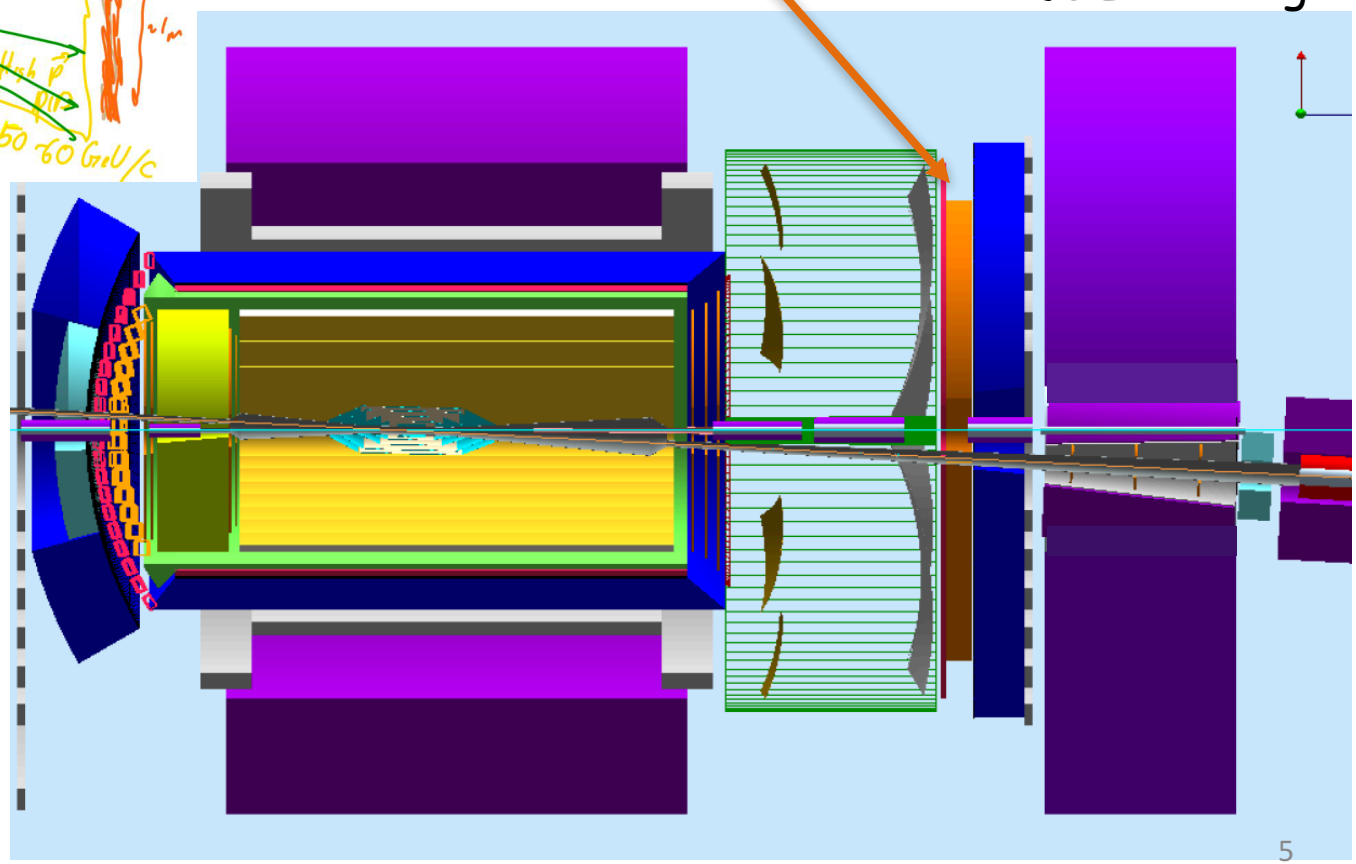
Hadron endcap

R&D tracking consortium

GEM-TRD/T

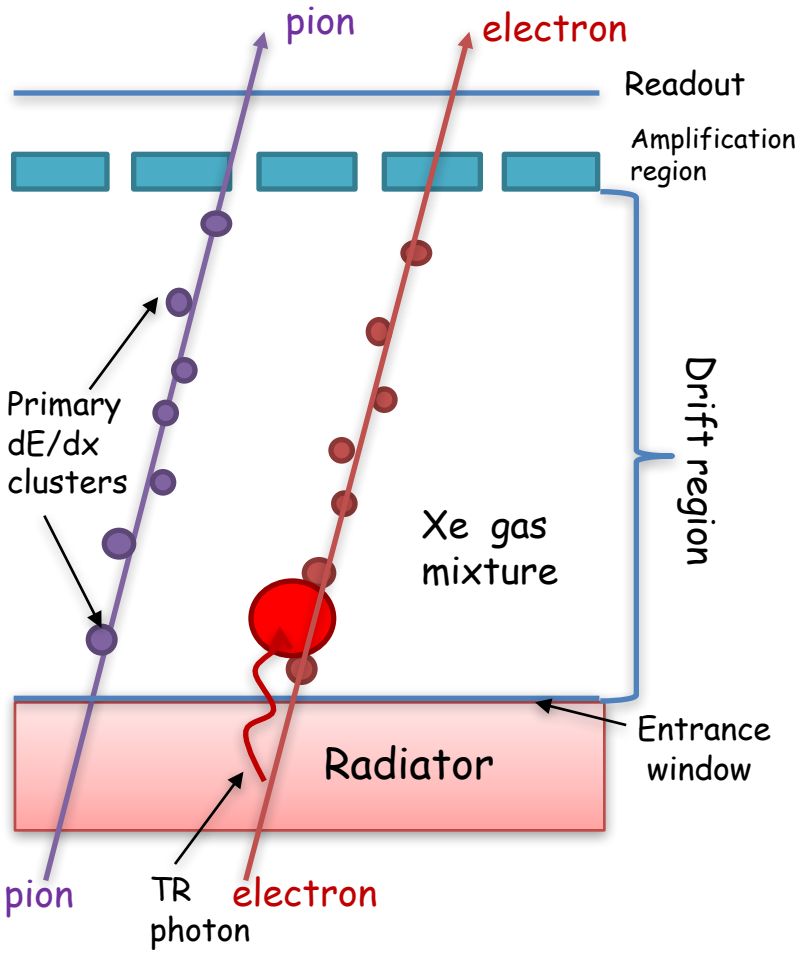


JLEIC design



GEM as Transition Radiation detector and tracker for EIC

- 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)
  - ✓ Increase drift region up to 2-3 cm (for the same reason).
  - ✓ Add a radiator in the front of each chamber (radiator thickness ~5-10cm)
  - ✓ Number of layers depends on needs: Single layer could provide e/pi rejection upto 10 with a reasonable electron efficiency.

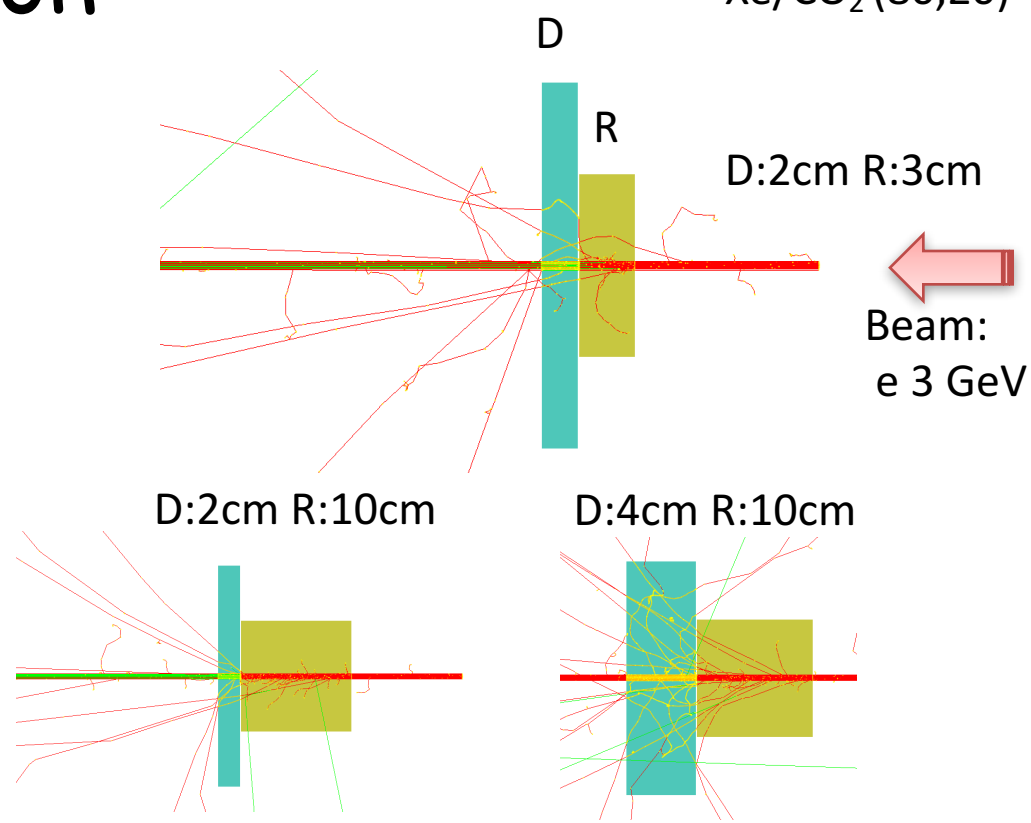


GEANT4 simulation

Xe/CO_2 (80,20)

Optimization:

- TR photon yield
  - Increase of Radiator
- Detection capability
  - Gas volume
  - Gas mixture
- Overall performance
  - Detector space
  - Decreasing "dead regions"
  - e/π rejection



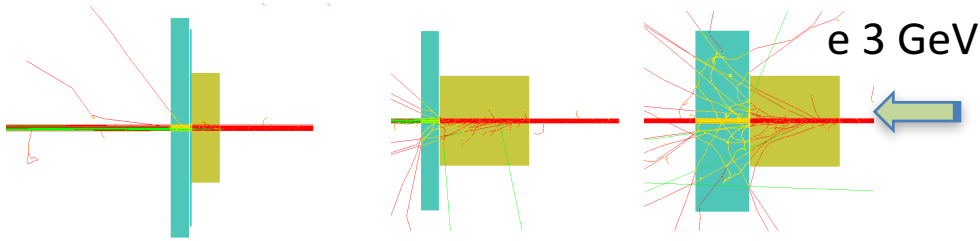
Parameters:

- ✓ Detector Gas Volume (D) : 1 – 4 cm
- ✓ Radiator Volume (R): 3-10 cm
- ✓ "Dead region": gap, cathode material(Al, Cu, Cr)
- ✓ Gas mixture: Xe/CO_2 , Ar/CO_2 …
- ✓ # layers:1,2,3 …

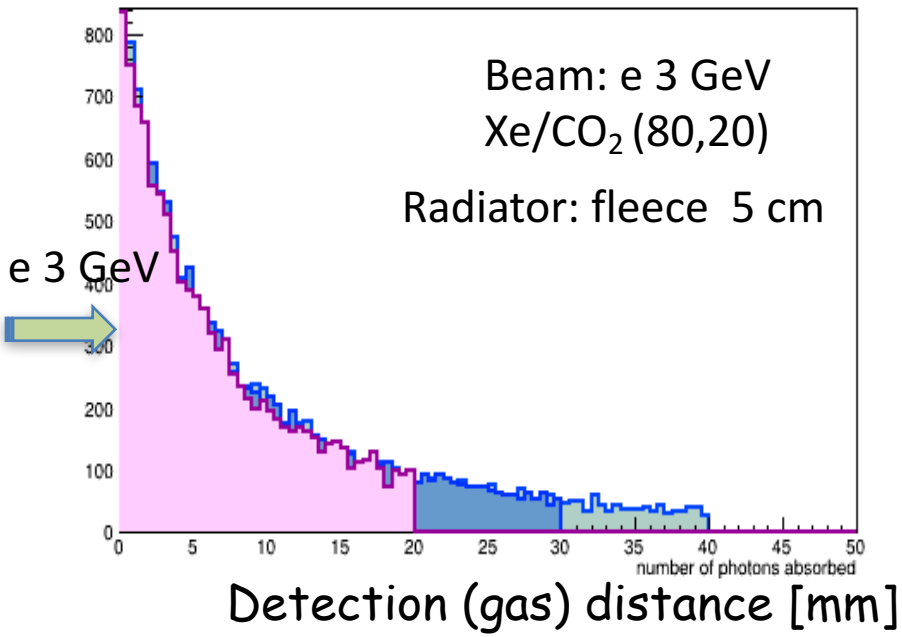
Output values:

- # TR photons produced
- # TR photons detected
- dE/dx (including TR)
- e/π rejection

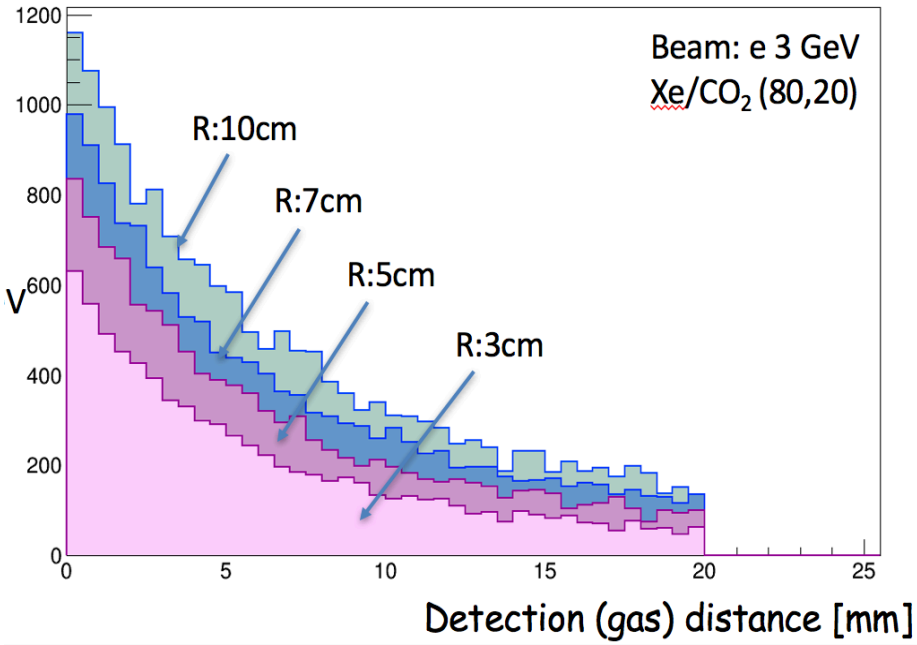
GEANT4 simulation



Energy deposition from TR photons along the track

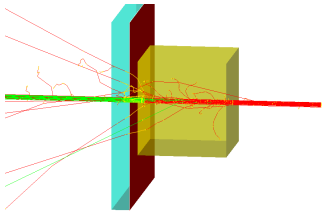


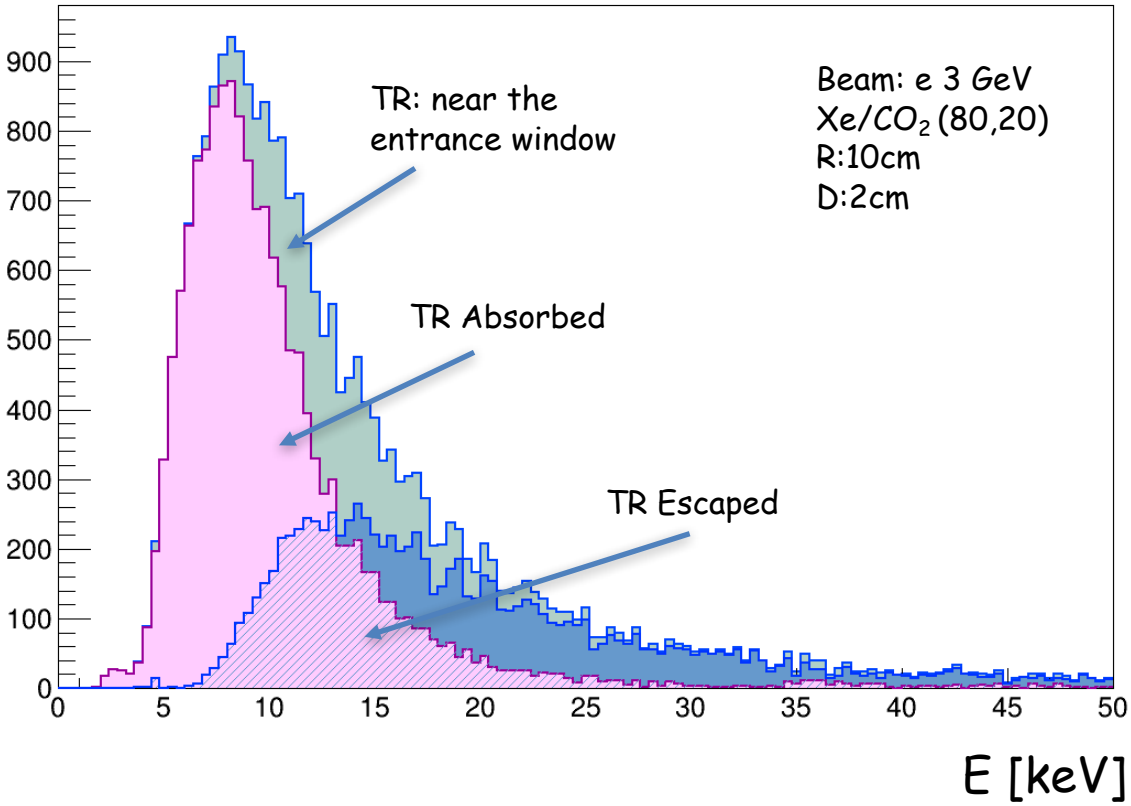
Energy deposition from TR photons along the track



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

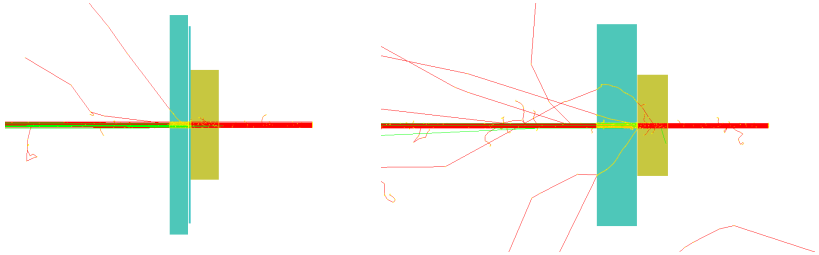
Energy spectrum of TR photons



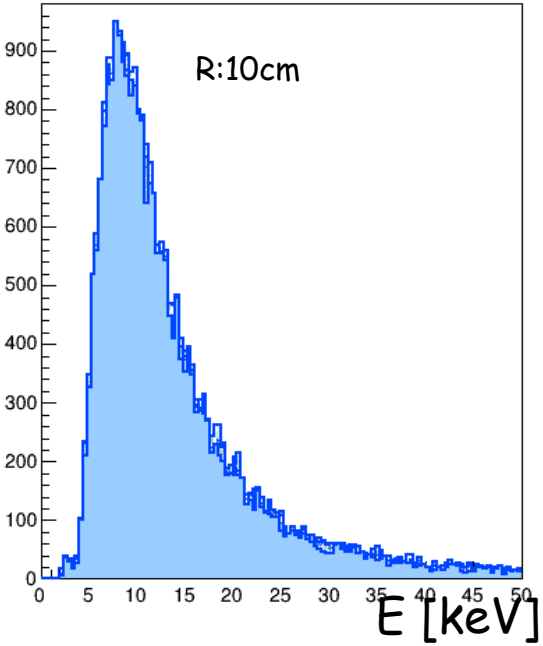


- Most energetic part of TR spectrum escapes detection.

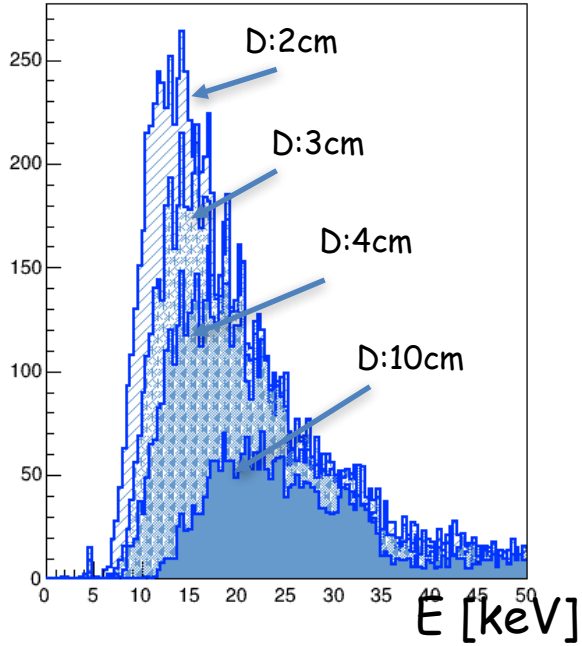
Energy spectrum & yield (fixed radiator volume)



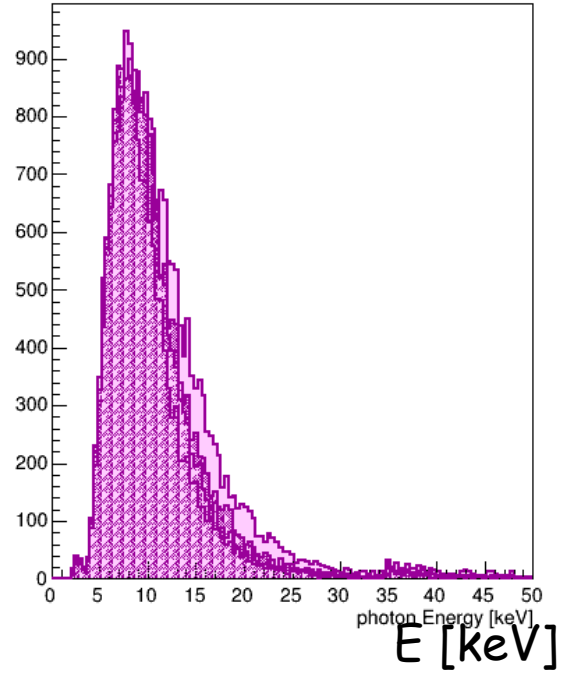
TR: near the entrance window



TR: Escaped detection



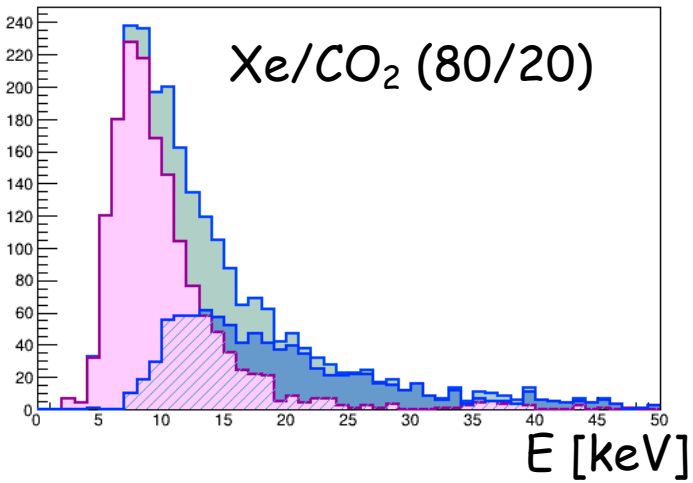
TR: Absorbed

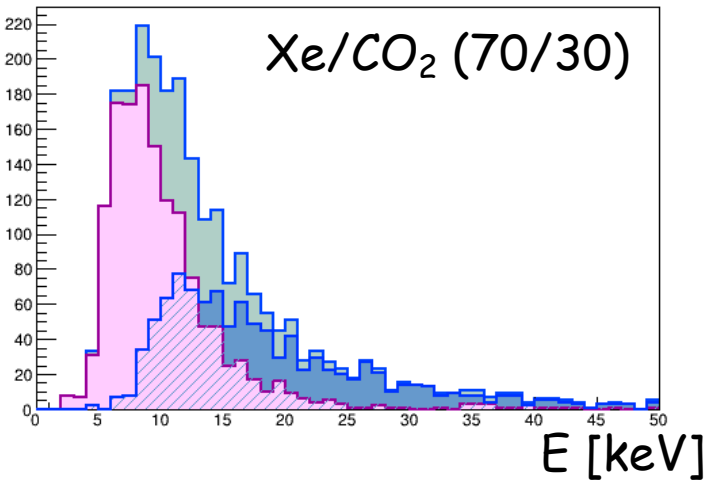


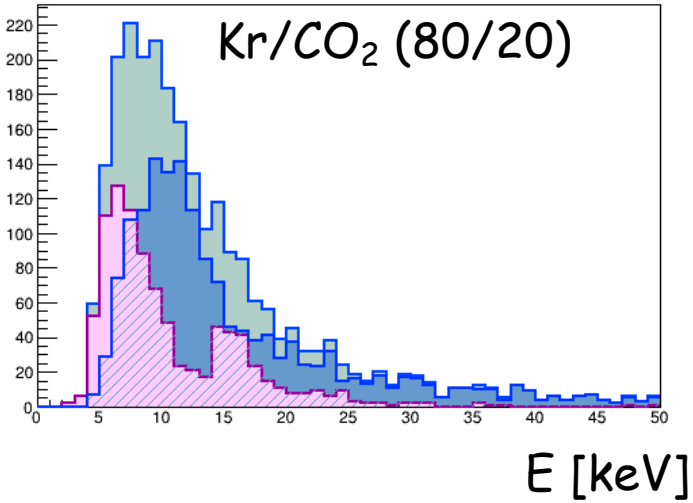
- Increase of a gas volume helps to detect energetic part of TR spectrum

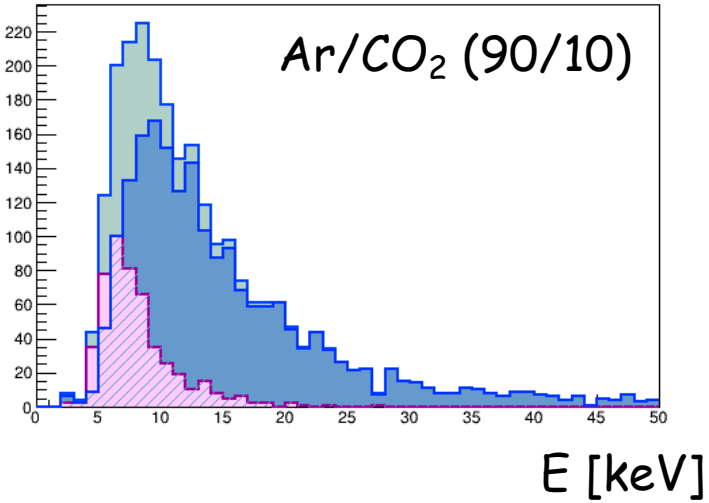
Different Gas mixtures

D:2cm, R:10cm



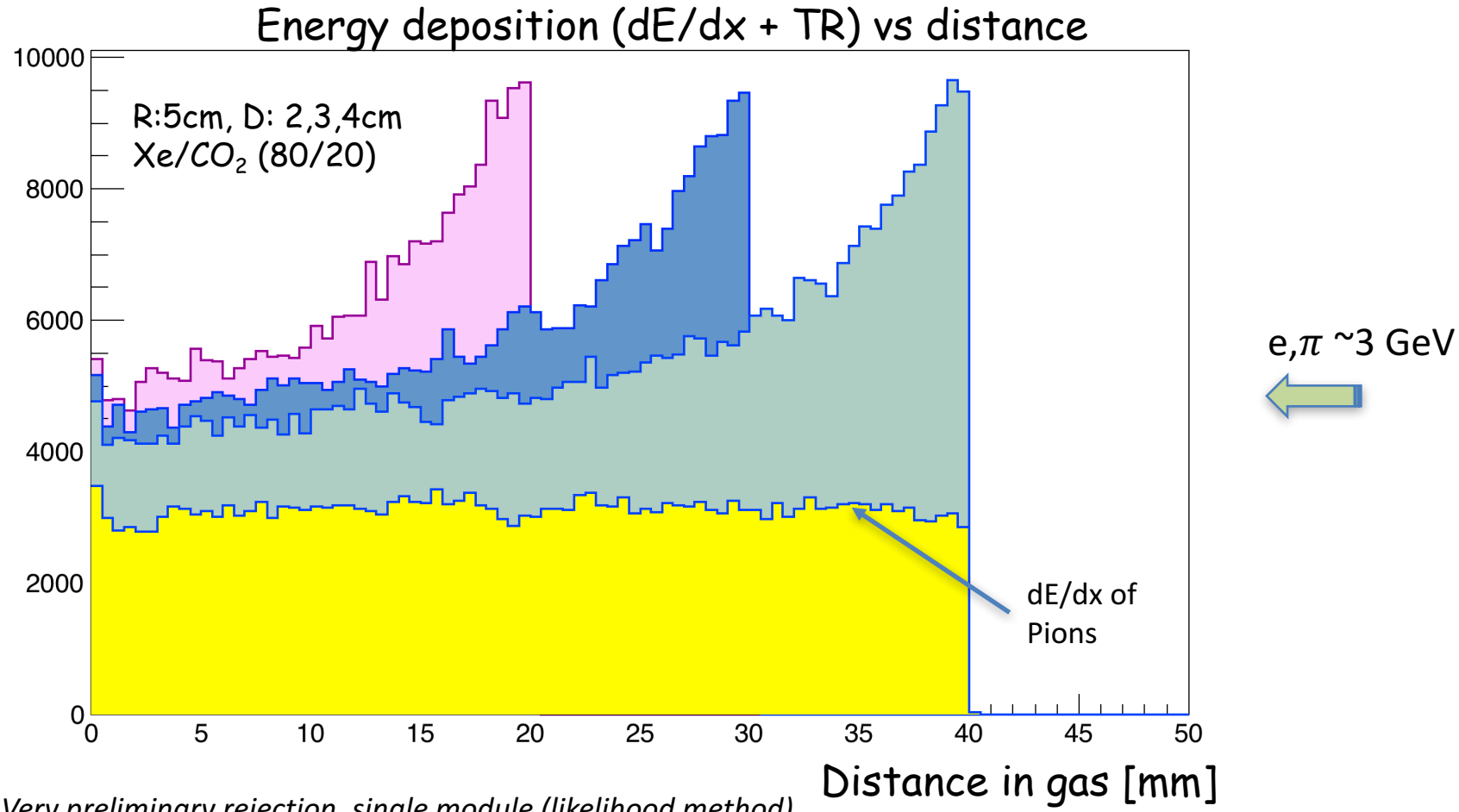






Yulia Furletova

GEANT4: electron and pion comparison



Very preliminary rejection, single module (likelihood method)

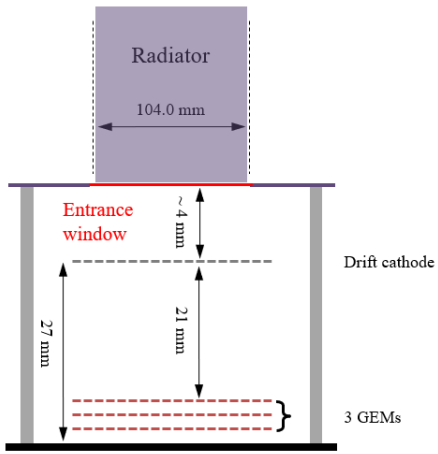
	90% eff	**70% eff**
2cm Xe	2.5	12
4cm Xe	4.5	17

GEANT4: Next Steps

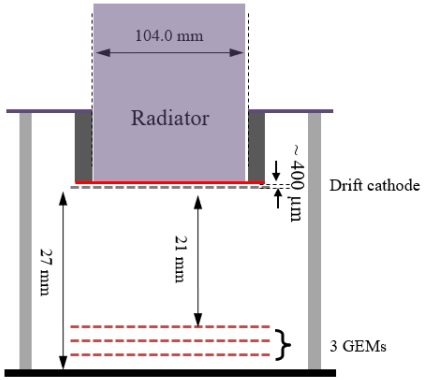
- We performed a GEANT4 simulation of a single GEMTRD layer
- Digitalization (need an input from test beam)
- Multi-layer configuration and e/pi rejection from GEMTRD layers

GEM -TRD/T prototype

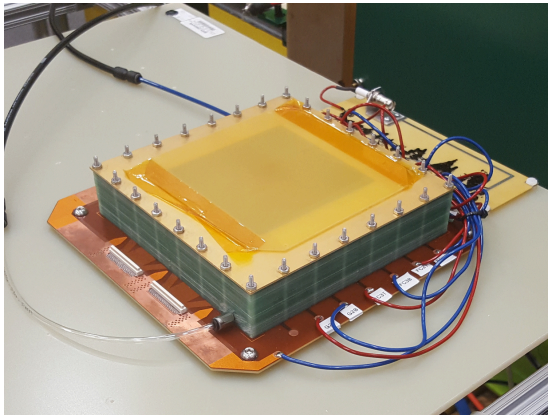
Additional funds , provided by Jefferson Lab:
-New prototype, with modifications at the entrance window
-New interface board for readout



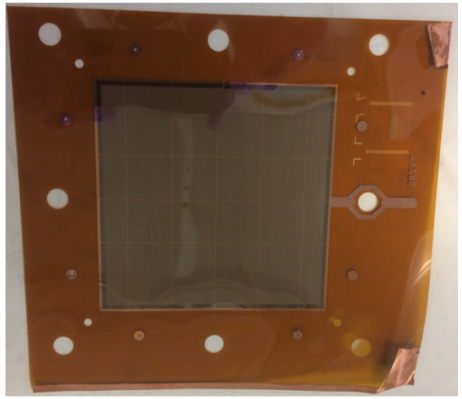
Old GEM-TRD: proto I



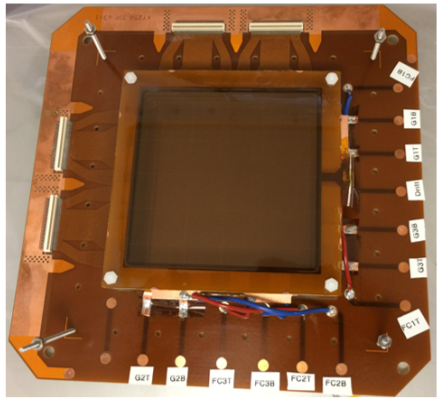
New GEM-TRD: proto II



	Material	Thicknesses
Entrance window foil	Kapton	25 µm
Entrance gas volume	Xe-CO2	400 µm
Drift foil	Chromium + Kapton	Chromium: 0.2 µm Kapton: 50 µm
Drift volume	Xe-CO2	21 mm
3 GEM foils	Cu-Kapton-Cu	Chromium: 6 × 5 µm Kapton: 3 × 50 µm



Cr drift cathode foil

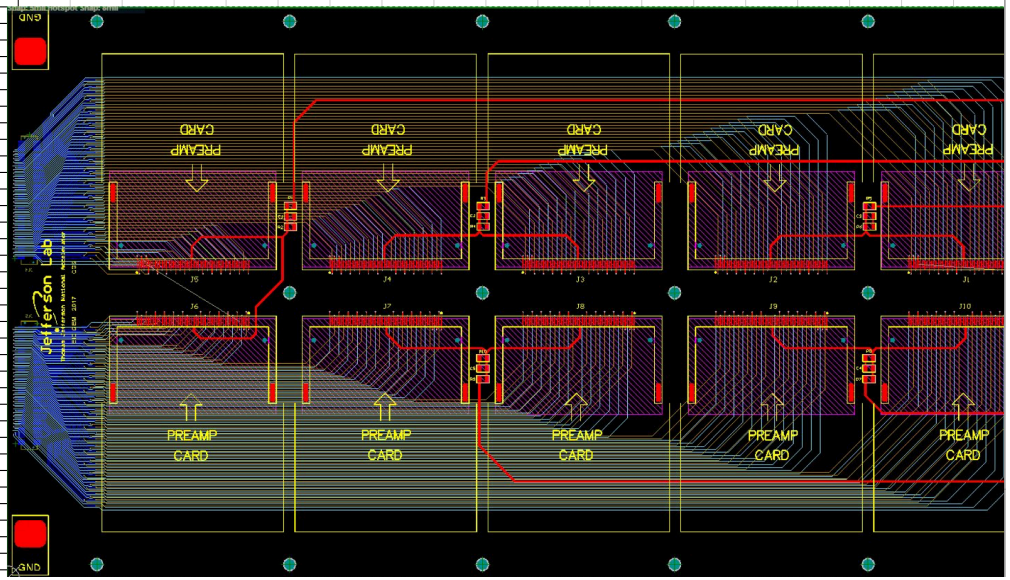


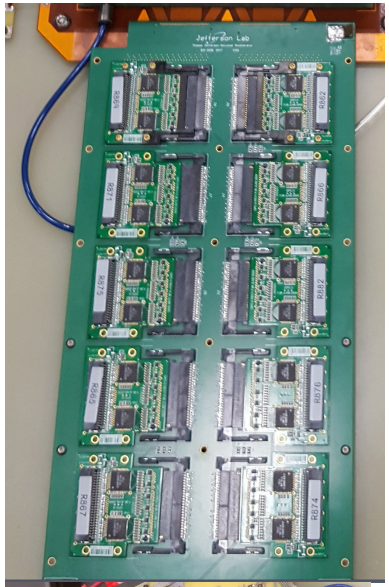
Drift cathode and GEM stack on new R/O board

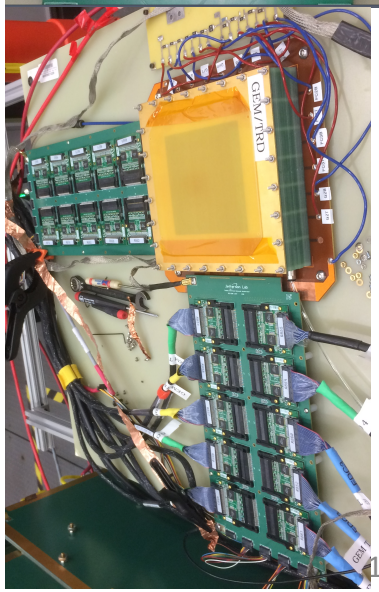
New interface board

a special thanks to
Fernando Barbosa and Chris Stanislav !!!

J15	Channel	Pre-Amp	Pre-Amp Pin
1	GND		
2	CH121	J6	50
3	CH122	J6	49
4	CH123	J6	48
5	CH124	J6	47
6	CH125	J6	46
7	CH126	J6	45
8	CH127	J6	44
9	CH128	J6	43
10	CH129	J6	42
11	CH130	J6	41
12	CH131	J6	40
13	CH132	J6	39
14	CH133	J6	37
15	CH134	J6	36
16	CH135	J6	35
17	CH136	J6	34
18	CH137	J6	33
19	CH138	J6	32
20	CH139	J6	31
21	CH140	J6	30
22	CH141	J6	29
23	CH142	J6	28
24	CH143	J6	27
25	CH144	J6	26
26	CH145	J7	50
27	CH146	J7	49
28	CH147	J7	48
29	CH148	J7	47
30	CH149	J7	46
31	CH150	J7	45
32	CH151	J7	44
33	CH152	J7	43
34	CH153	J7	42
35	CH154	J7	41







- compatible with JLAB Flash-ADC system
- Each board holds 10 preamplifiers, each preamplifier connects to 24 GEM strips resulting on a readout of 240 GEM strips per each readout board or X/Y coordinate.
- A pre-amplifier has GAS-II ASIC chips (3 chips per each preamplifier card) and provides 2.6 mV/fC amplification. A preamplifier has a peaking time of 10 ns. It consumes 50 mWatt/channel and has a noise <0.3 fC. The dynamic range of preamplifiers (where it is linear) is about 200 fC.

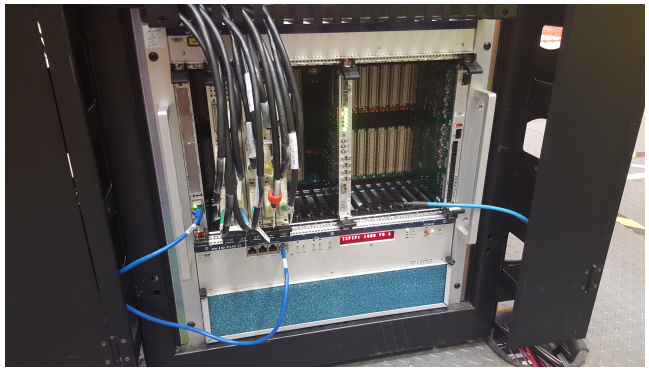
- Covers up to 2.4 (32) μs of a drift time.

DAQ, DQM

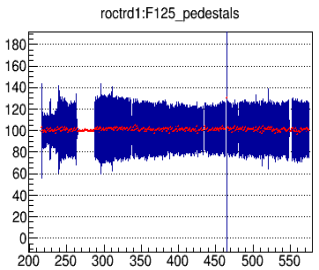
- new Data Acquisition (DAQ) system:

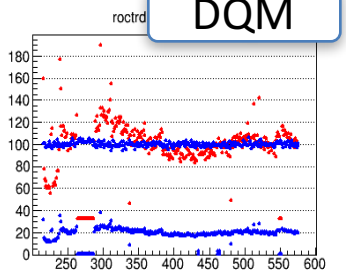
a standard JLAB DAQ configuration that consists of a VME crate with readout controller running Linux, Flash-ADC boards and a trigger interface board. The DAQ software is based on CODA libraries, which were also developed at JLAB.
All the DAQ components were borrowed from JLAB (Hall-D). We used 4 fADC125 boards, with 72 channels which were grouped into 3 connectors on the front panel.

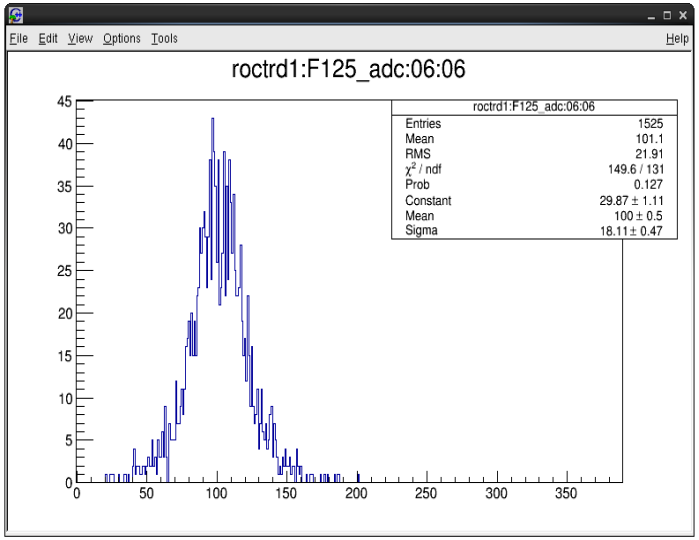
- new Data Quality Monitoring (DQM)
- new analysis software.



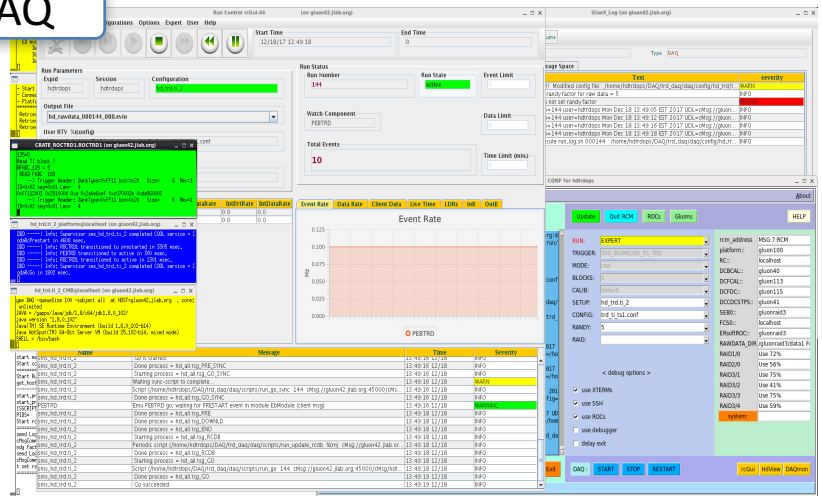
DQM







DAQ



HV, GARFIELD and MAGBOLTZ simulation

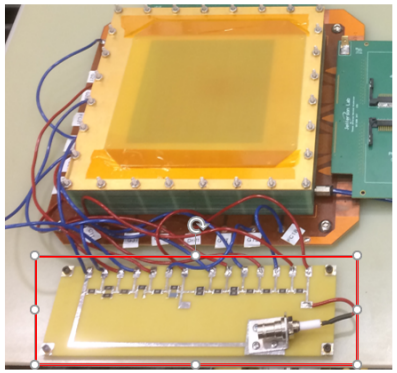
HV divider for GEM-TRD with Gaps 21-2-2-2,

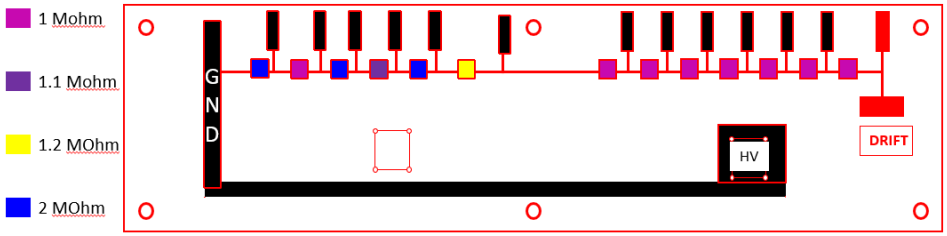
Total divider = 16.3 MΩ

- Amplification divider = 9.3 MΩ
- Drift divider = 7 MΩ

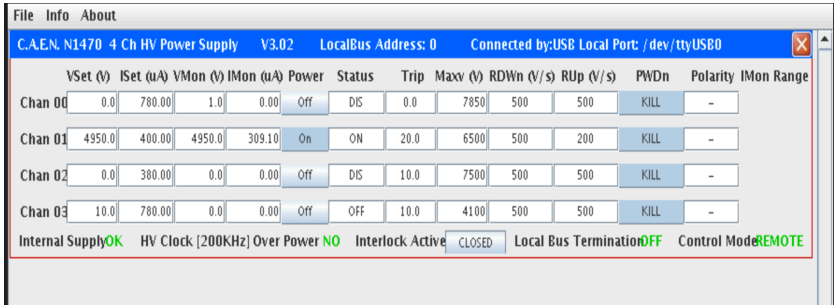
Xe-CO2 1n Hall D ⇨ Operating voltage HV = 6500 V

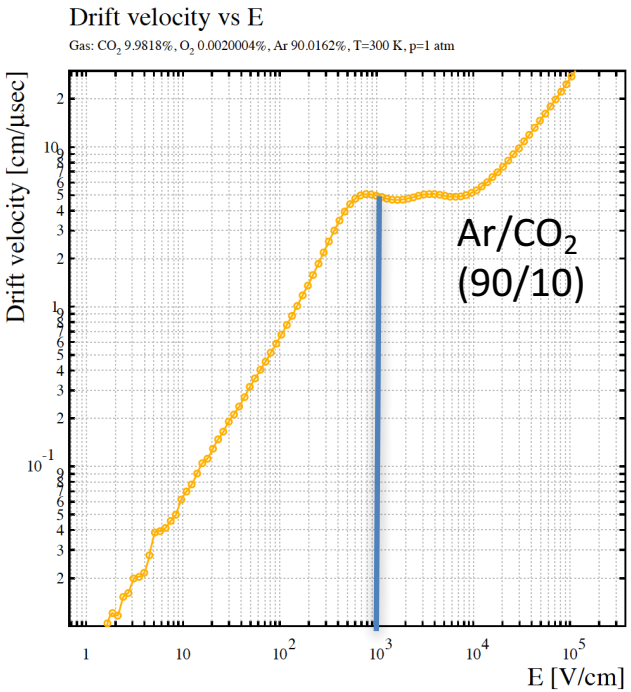
- HV drift region = (6500 V × 7) / 16.3= 2790 V
- Electric field in the drift = 1.33 kV/cm

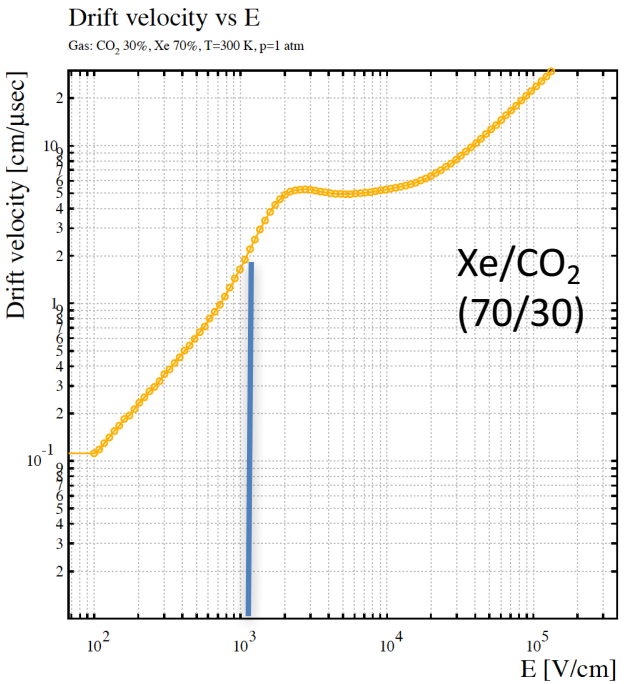




6.5 kV for Xe-CO2, the field in the drift region is 1.33 kV/cm

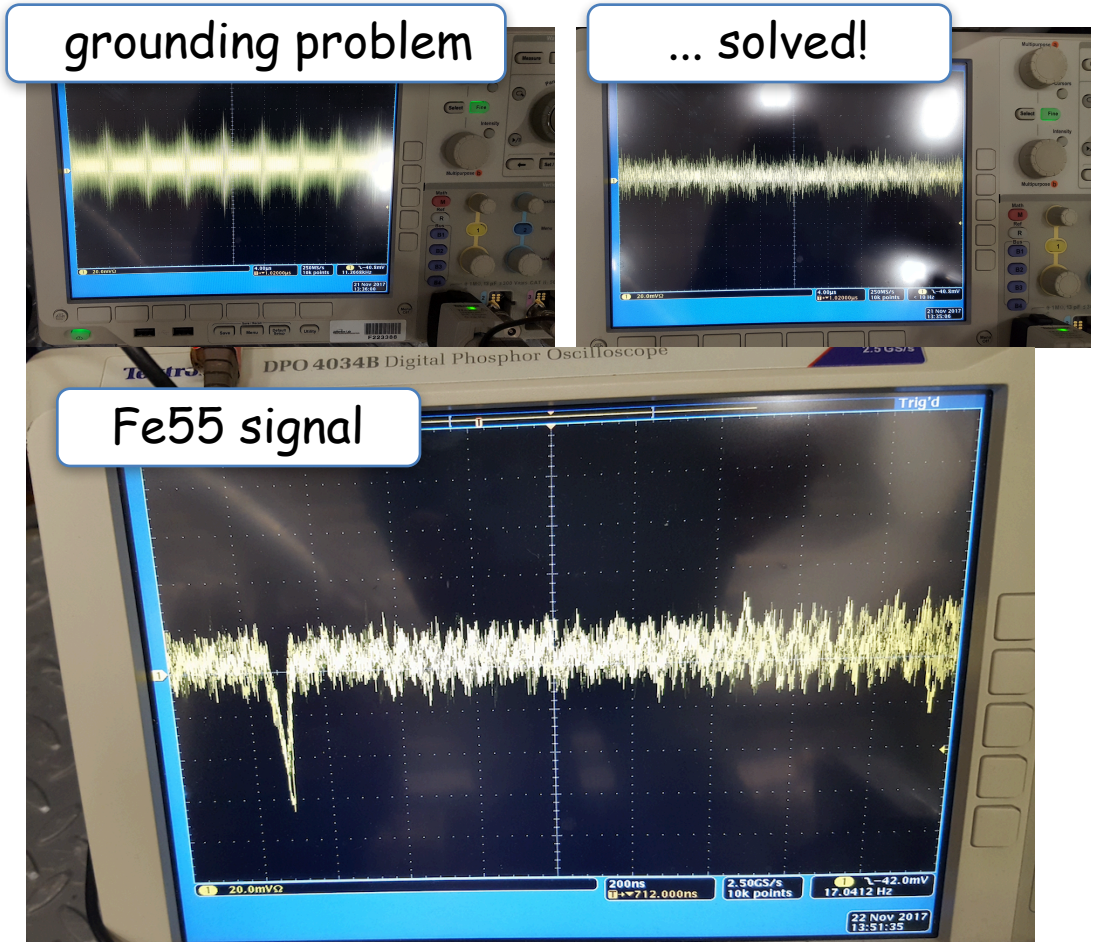






Fe^{55} test

- Prototype fully tested at UVA
- Problem with grounding at test beam solved.
- Performed a test with Fe55 source with Ar and Xe gas mixtures.
- HV adjustments.



Radiators

- For MC and testbeam we used ZEUS fleece radiator

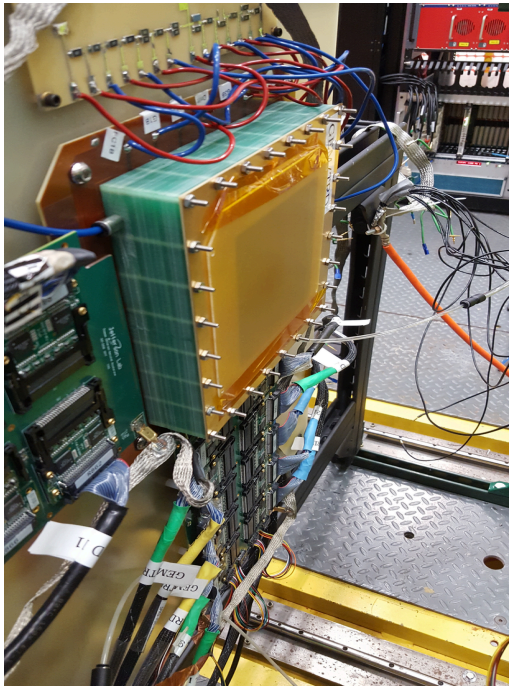
- Next:

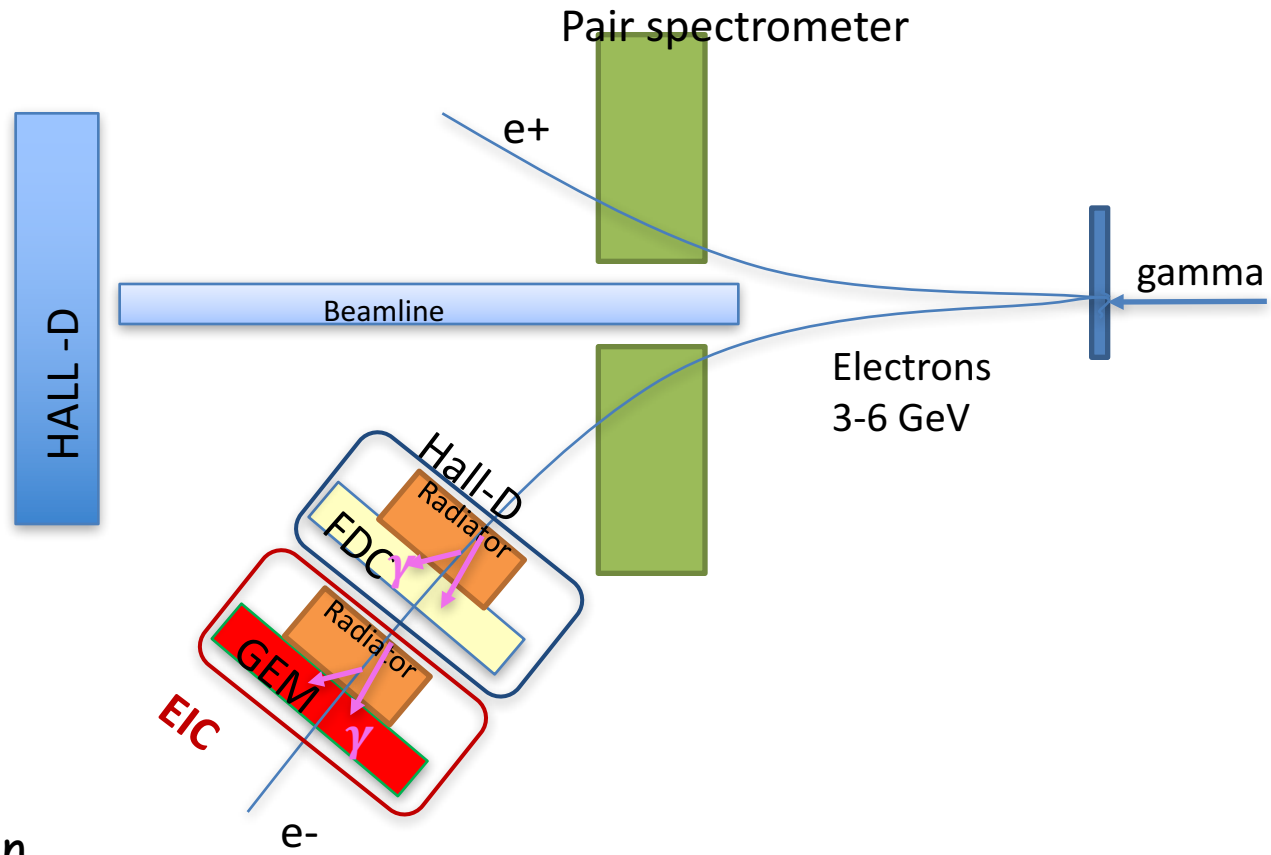
a) a stack of regular foils: 20-30μ mylar foils and 200-300μ air gap

b) HERMES radiator

c) R&D on a new radiators

Test Setup at JLAB HALL-D



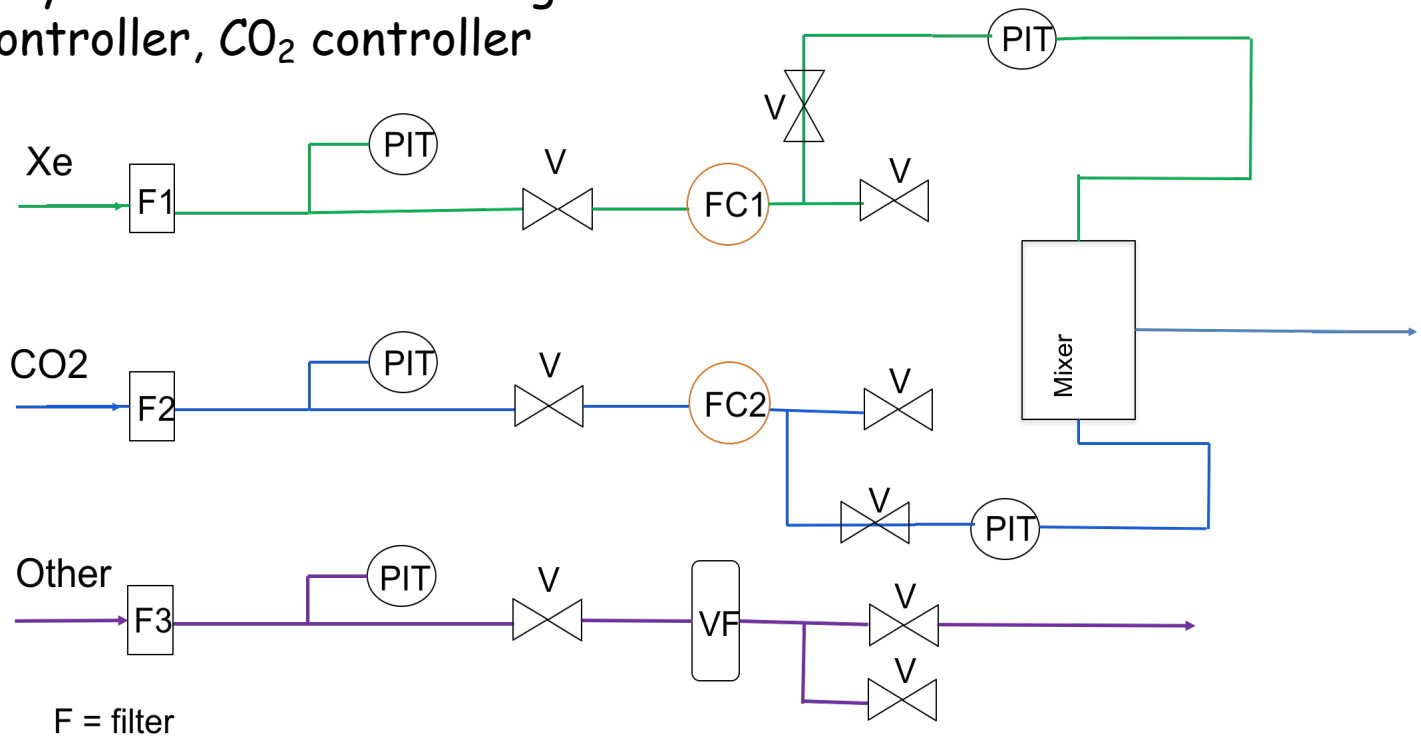


- Mechanical installation
(many thanks for Tom Carstens)

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

GAS system proposal

- Without a re-circulation and a purification system (too early stage of R&D)
- Mixing system to mix custom gas concentrations
- Flow controller, CO_2 controller



F = filter
PIT = pressure inducer transmitter
V = manual valve

FC = flow controller
PIT = pressure indicating transmitter
VF = variable area flow meter

Proposed and Achieved

- GEANT4 simulation of TRD setup with GEM detector (gas and radiator volumes) for a single layer operation.
    - Digitalization (need feedback from test beam)
- Multilayer operation
    - Estimate e/pi rejection factor for multi-layer configurations

- Built and tested new GEM based TRD prototype and optimized its performance.

- Using the existing facility at JLAB Hall-D perform a test with "known" radiators –ongoing

- Tests of other possible TR-radiators - ongoing

- Front-end electronic / DAQ :
    - Test new DAQ with Flash ADCs

- Test different Xe-gas mixtures: drift time, voltages and gas-gain, adjustments => test different HV scheme and new gas-mixing system.

- Tracking performance

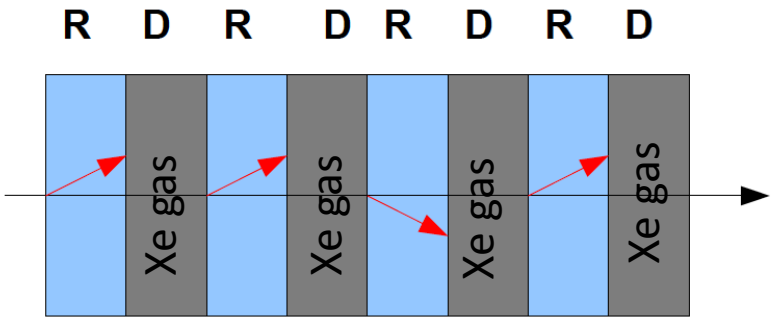
Summary

- Electron identification is very important for EIC physics. Due to a large hadron background expected in the forward (Hadron-endcap) region, a high granularity tracker combined with TRD functionality could provide additional electron identification - GEM-TRD/T
- GEANT4 simulation of GEM-TRD is ongoing.
- Test beam measurements are on the way
- Looking forward for exciting results!

Thank you!

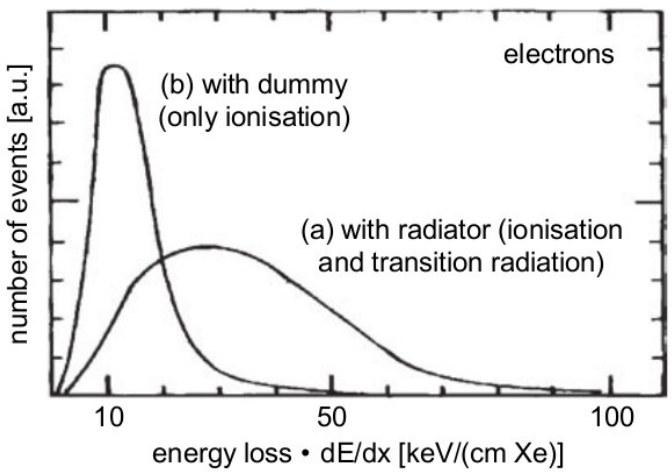
Backup

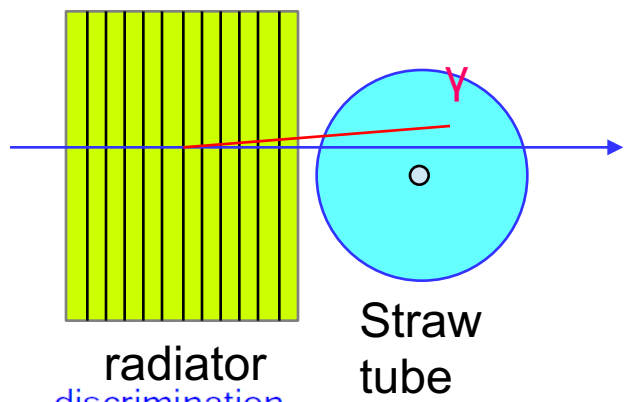
Xe -gas detectors

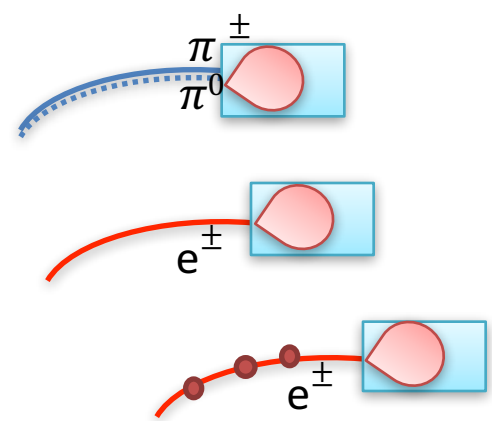


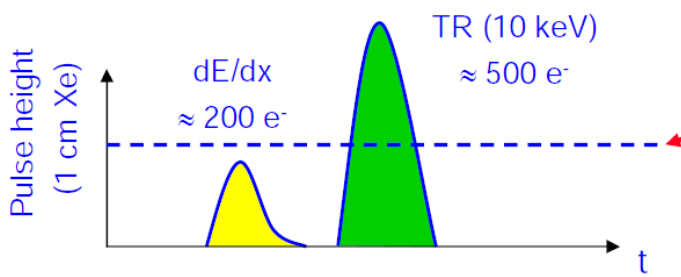
- Stack of radiators and detectors (sandwich)
- For "classical" TRD (straw, MWPC) gas is needed for better absorption of TR photons: high Z required => Xenon gas (Z=54)

- TRDs are not "hadron-blind" ! they see all charged particles dE/dx:
  - Intrinsic problem: detector "sees" both TR & dE/dx
  - TR photons (5-30 keV) over a dE/dX background (2-3 keV).





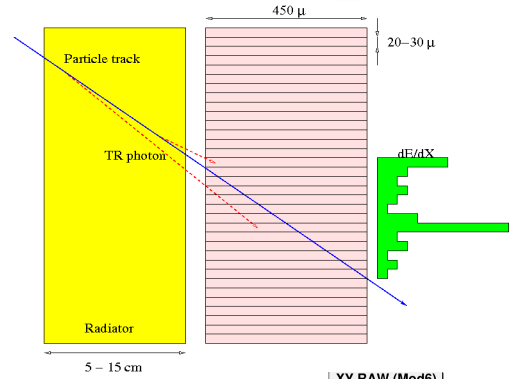


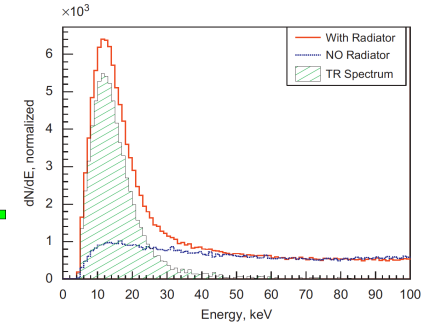


discrimination
by threshold

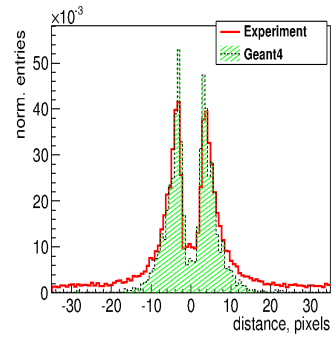
Silicon pixel TRD

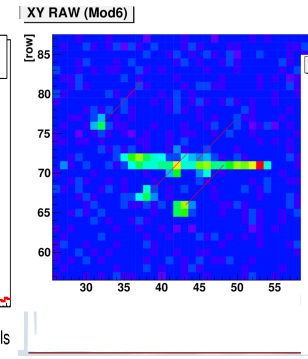
Problem: A huge dE/dX of particles in 300-700μm of silicon - about 100-300keV (TR photons 4-40 keV).

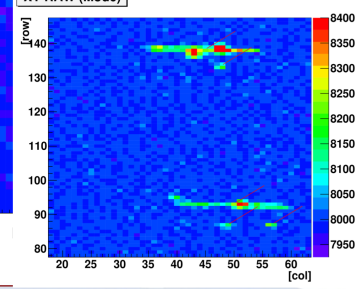




- **DEPFET silicon pixel detector**
  - Low noise, high S/N with 450 μm thick fully depleted bulk(sensitive area), pixel size – 20x20μm^2 .
  - TR photons are clearly visible and separated from track by a few pixels!



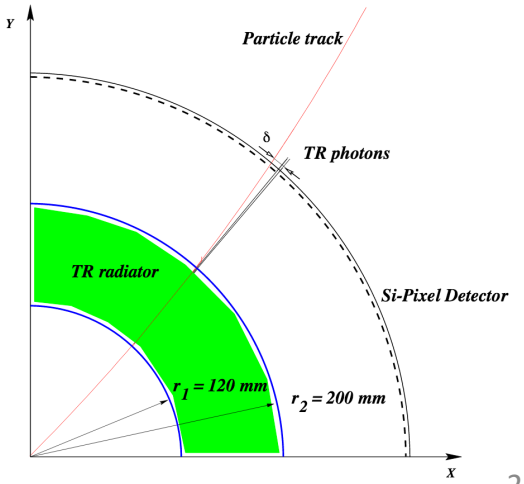




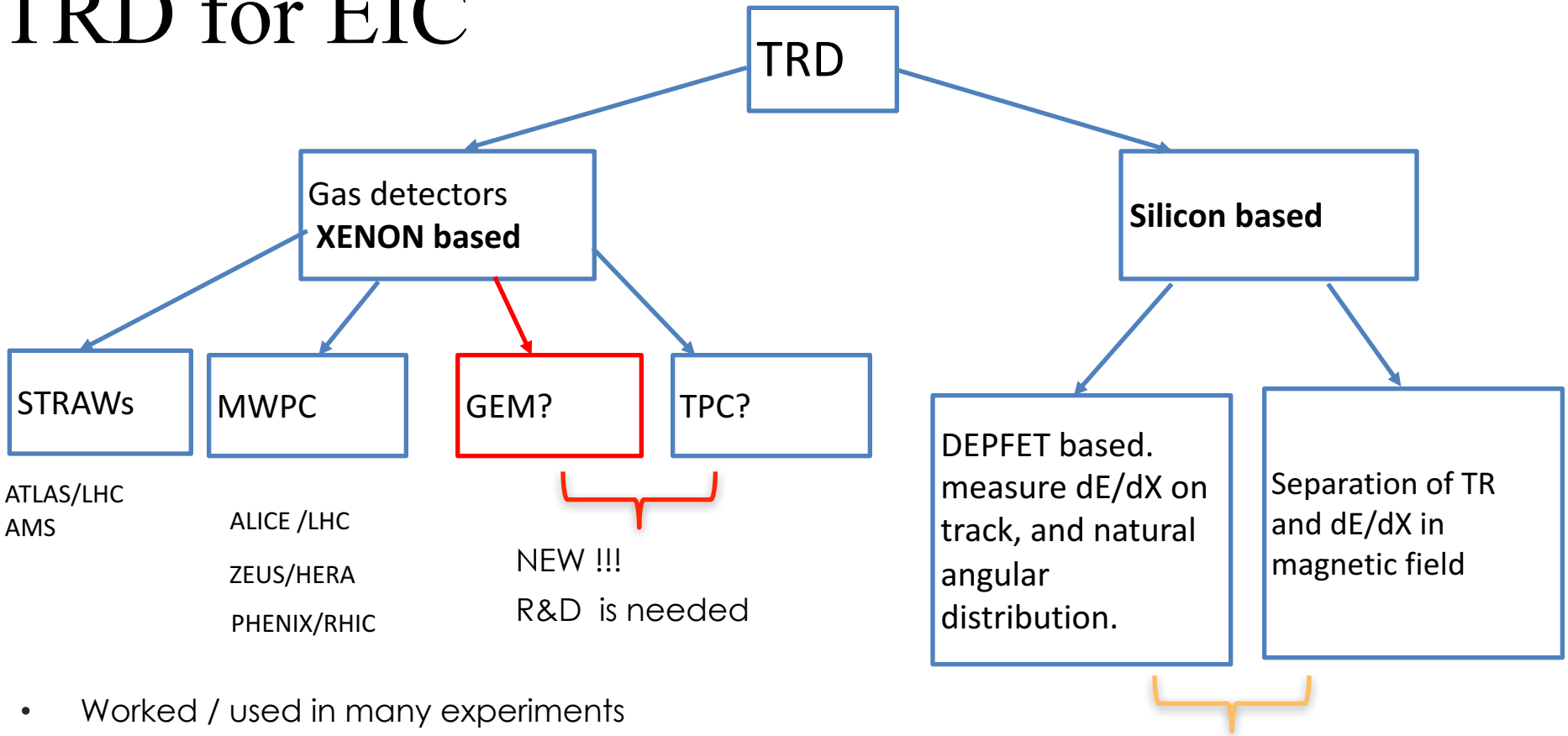
"New transition radiation detection technique based on DEPFET silicon pixel matrices", J.Furletova, S. Furletov, NIM-A 2010, http://dx.doi.org/10.1016/j.nima.2010.06.342
"Geant4 simulation of transition radiation detector based on DEPFET silicon pixel matrices", J. Furletova,S. Furletov, DOI: 10.1016/j.nima.2012.05.009

- **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)



TRD for EIC



- Worked / used in many experiments
- Could cover large area.
- X/X0 ~0.2 % for 4cm of Xe
- X/X0 ~1.5% for 10 cm of radiator
- Problem: Xenon is very expensive => gas purification system is needed.

- NEW !!! R&D is needed
- X/X0 ~1.5% for 600μm of Silicon
- X/X0 ~1.5% for 10cm of radiator
- Problem: price for DEPFET detector => not for large areas => may be for Vertex?