GEM based Transition Radiation detector/ tracker

Yulia Furletova on behalf of GEMTRD eRD22 group

Outline

- Physics motivation
- Intro into TRD
- Test beam setup
- Analysis
- Conclusions

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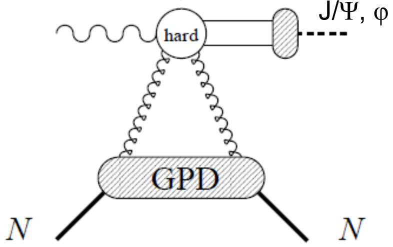
- Temple University
  - Matt Posik
  - Bernd Surrow

Electron identification (e/hadron separation)

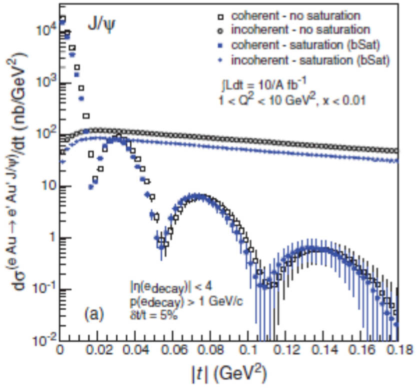
- **GPD and Coherent Exclusive Diffraction (saturation)**

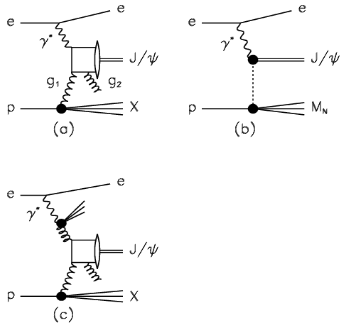


Br (J/ψ->e+e-) ~6%

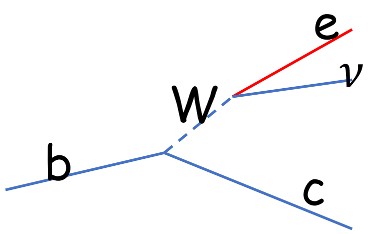
Br (J/ψ->μ+μ-) ~6%

Saturation Coherent Exclusive Diffraction



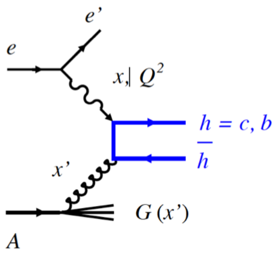


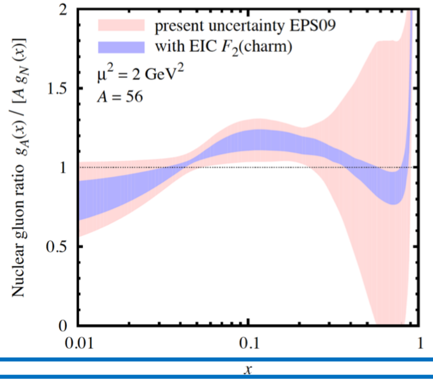
- **Heavy quark tagging**



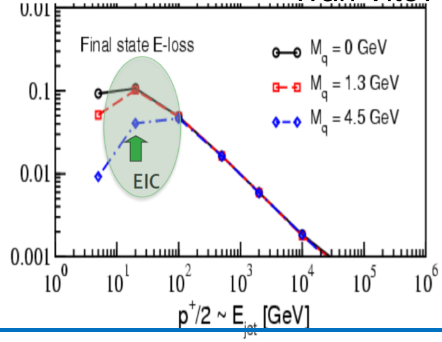
Br ($D^{\pm}$->e+X) ~16%

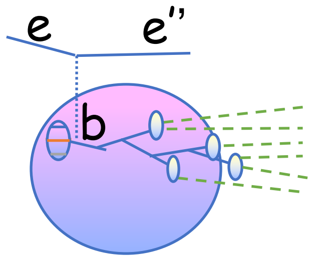
Br ($B^{\pm}$->e+ν+X_C) ~10%



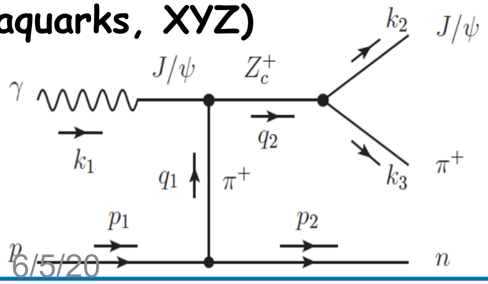


Ivan Vitev

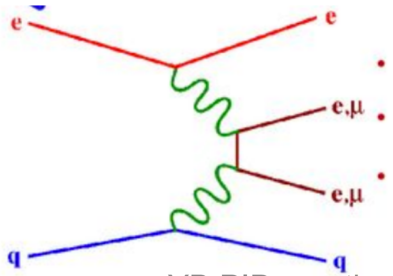




- **Exotic spectroscopy (pentaquarks, tetraquarks, XYZ)**



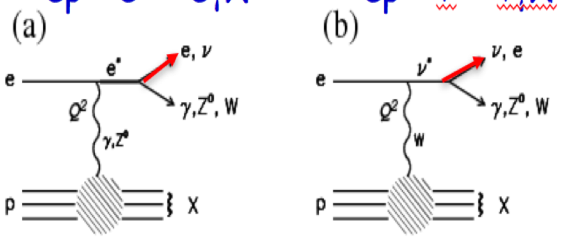
- **Multi-leptons**



- **Other BSM physics**

ep-> e*-> eγX

ep-> ν*->νγX

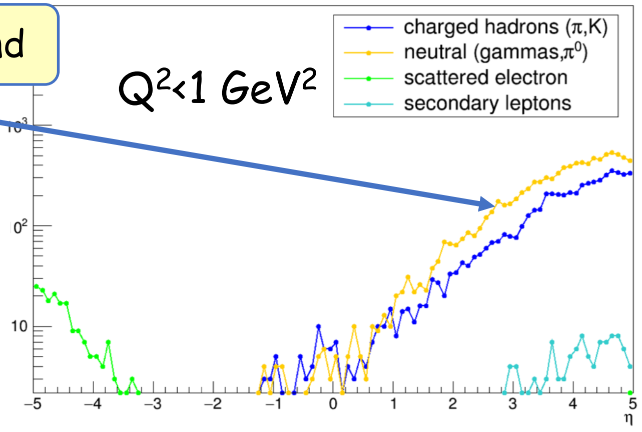


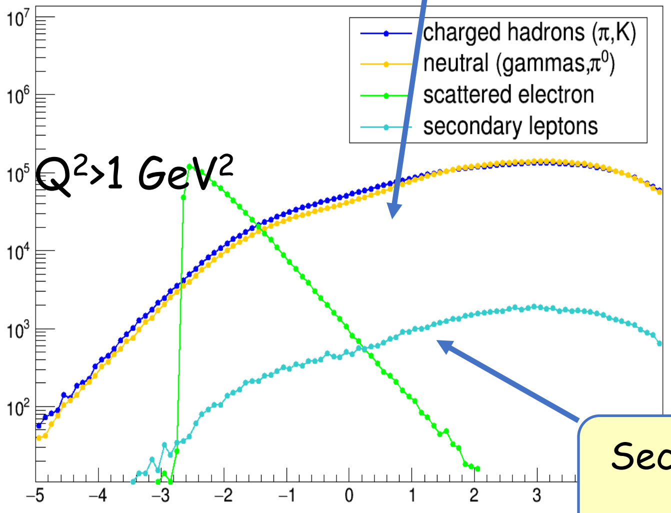
Electron/hadron separation

- The main detector for e/hadron separation is a Calorimeter. Also dE/dx in tracking detectors, as well as Cherenkov detectors could be used in the limited momentum range.
- TRD offers high e/h rejection for electrons in 1-100 GeV range

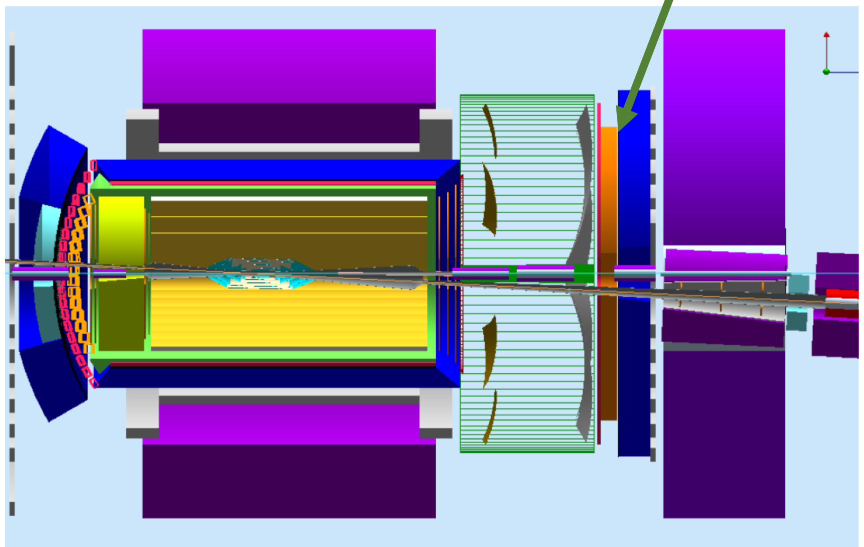
- Hadron end-cap
- between dRICH and EMCAL (extra tracking point)

High hadron background



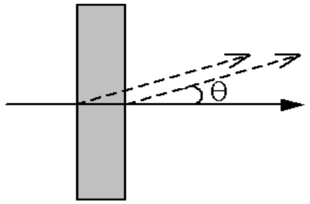


Secondary electrons, pt>100MeV



Transition Radiation

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



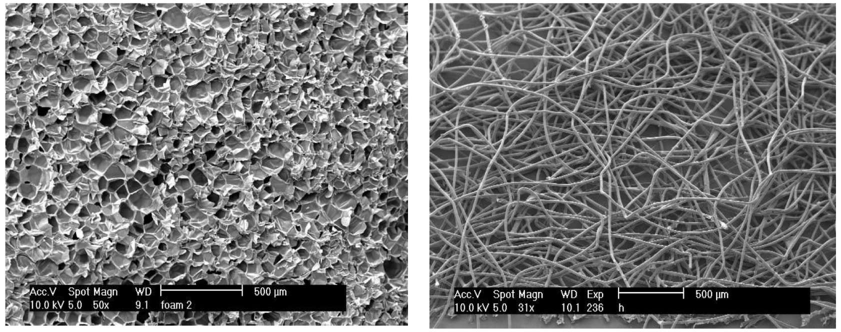
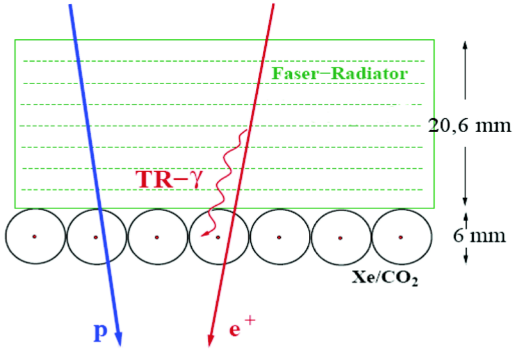
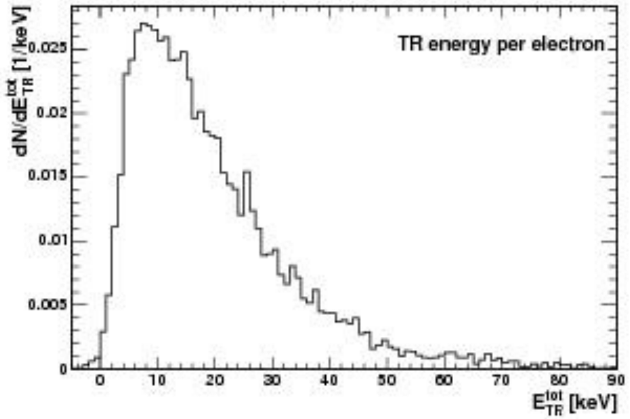
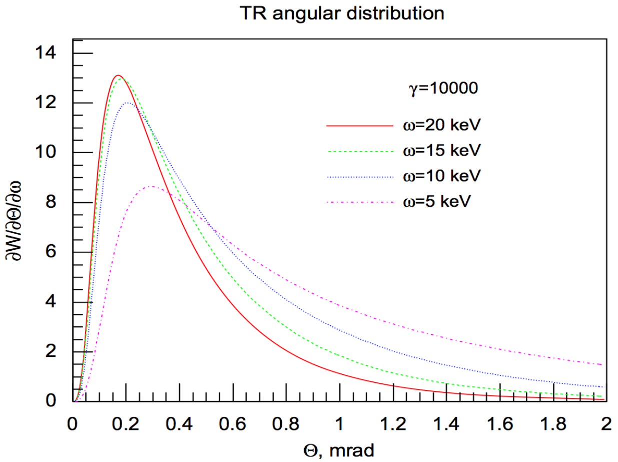


Figure 2: Electron microscope images of a polymethacrylimide foam (Rohacell HF71)(left) and a typical polypropylene fiber radiator (average diameter ≈ 25 μm) (right) [52].

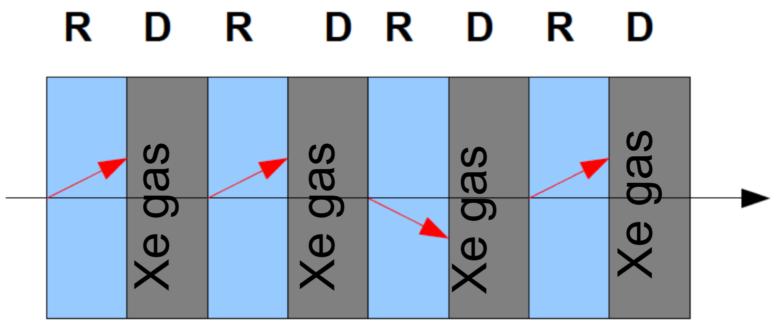






- the probability to emit one TR photon per boundary is of order α~1/137. Therefore multilayer dielectric radiators are used to increase the transition radiation yield, typically few hundreds of mylar foils.
- TR in X-ray region is extremely forward peaked within an angle of 1/γ
- Energy of TR photons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

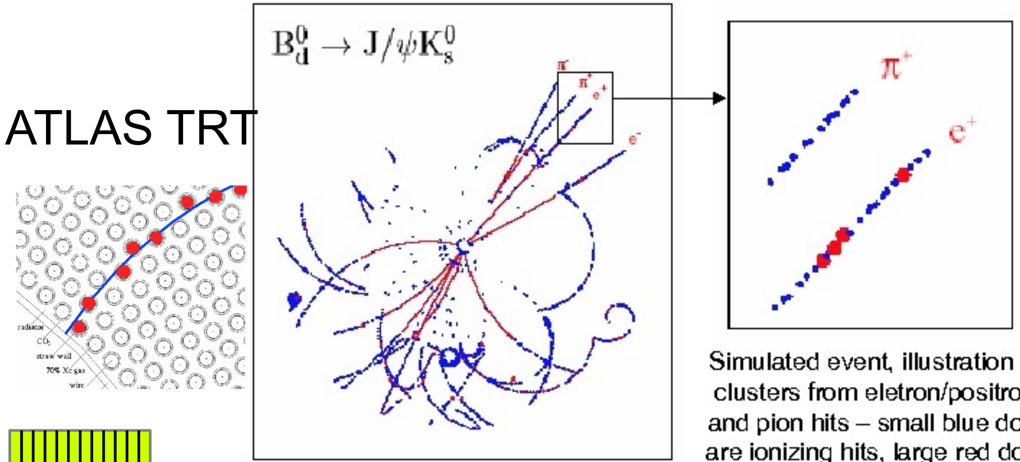
How easy to detect Transition Radiation ?



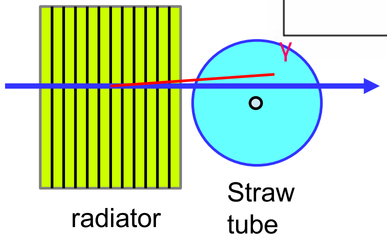
- Stack of radiators and detectors (sandwich)
- For "classical" TRD (straws, MWPC) gas with high Z is required for better absorption of TR photons: Xenon gas (Z=54)
- TRDs are not "hadron-blind" ! they see all charged particles dE/dx
- Several methods exist to identify TR photons on the top of dE/dx:
  (TR photons (5-30 keV) over a dE/dX background in Xe gas (2-3 keV)).

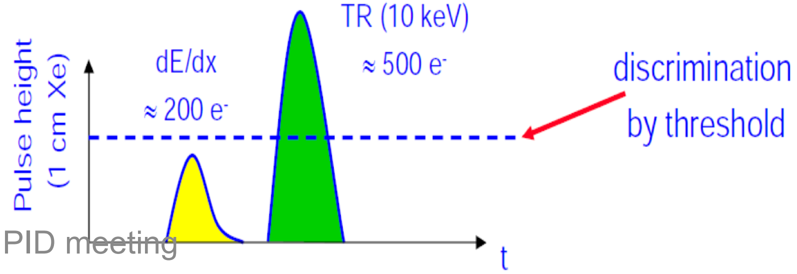
> - **Discrimination by threshold** (ATLAS)
> - ***Average pulse height along adjacent pads (or along a track)*** (ALICE) => (next slide)

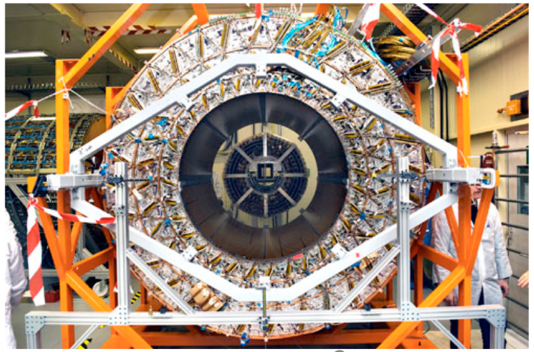
ATLAS TRT



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

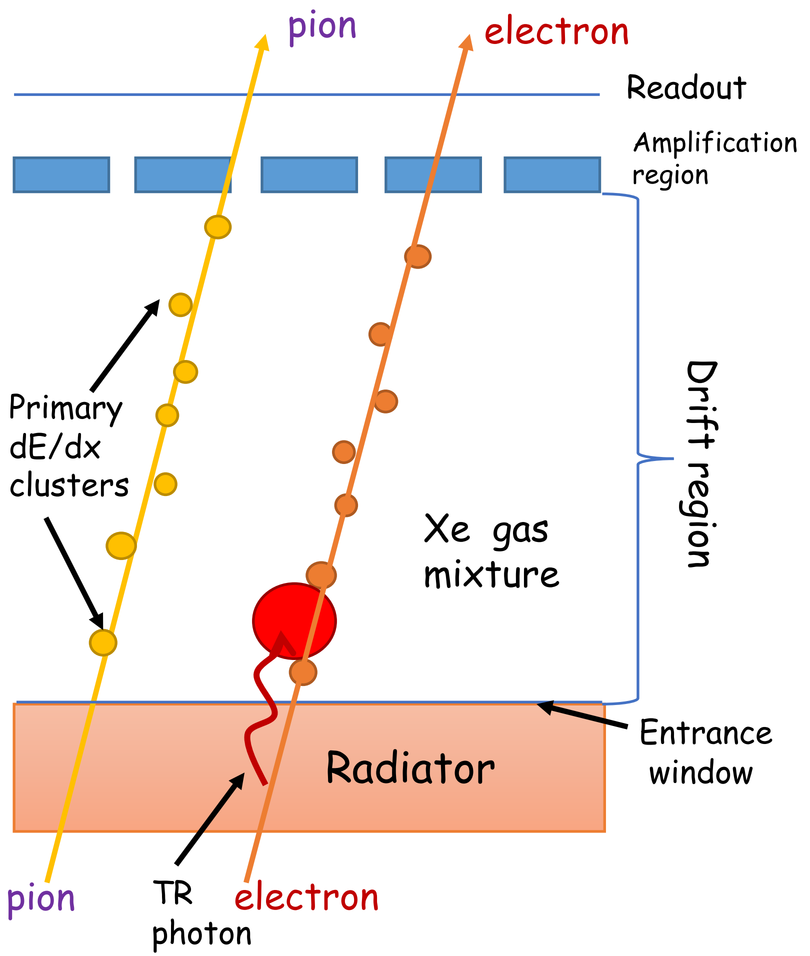






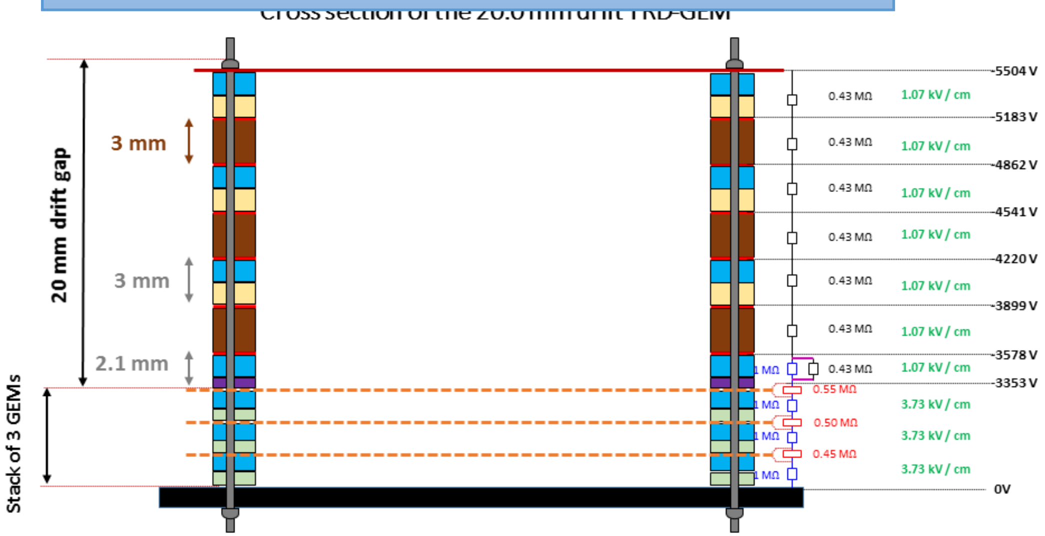
GEM as Transition Radiation detector and tracker for EIC (eRD22)

- 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 at level of 10 with a reasonable electron efficiency.

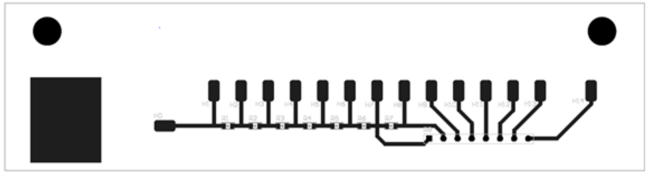


GEM -TRD/T prototype @ UVA

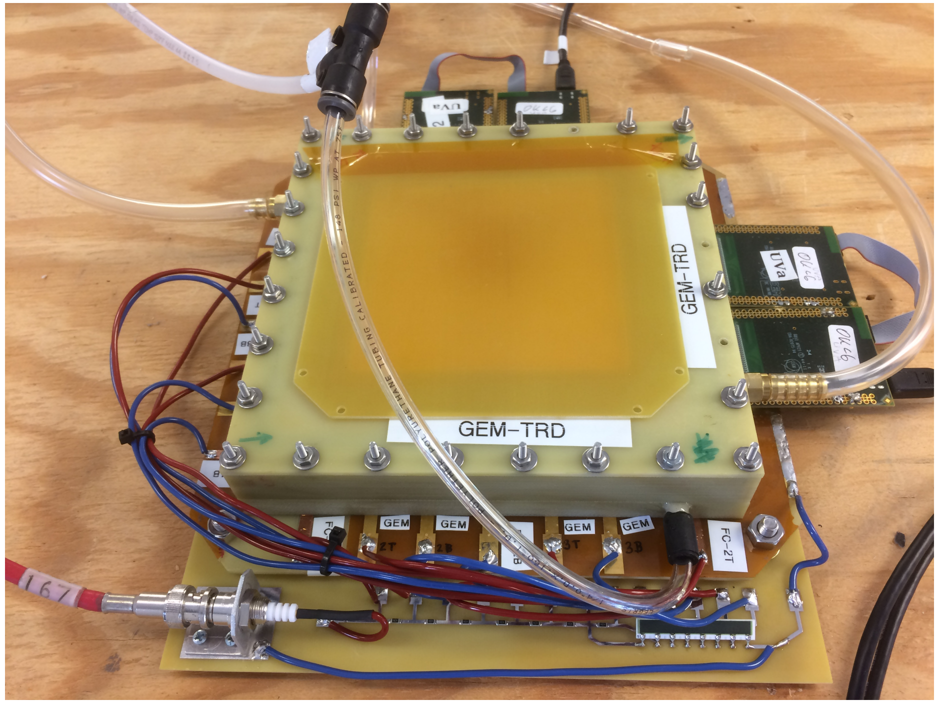
GEM-TRD/T cross section, 21mm drift volume



Drawing for the resistive divider



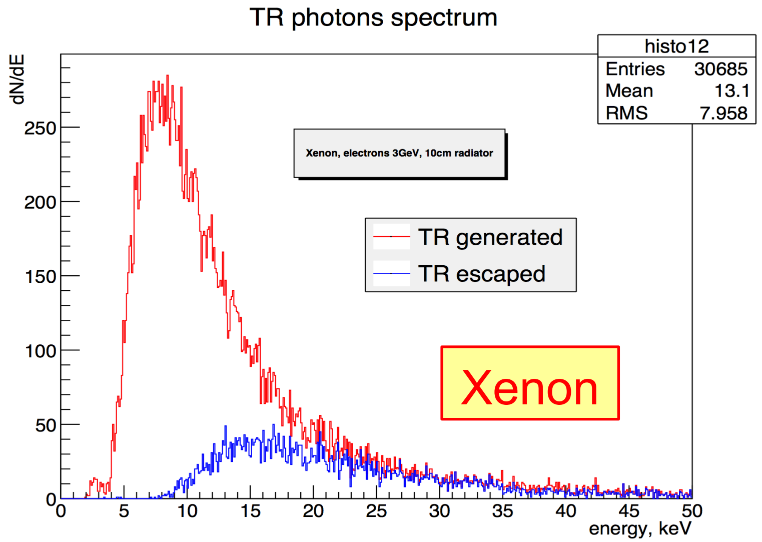
HV 5504 V,
Resistive Divider = 7.404 MΩ,
Max current = 747.3 μA

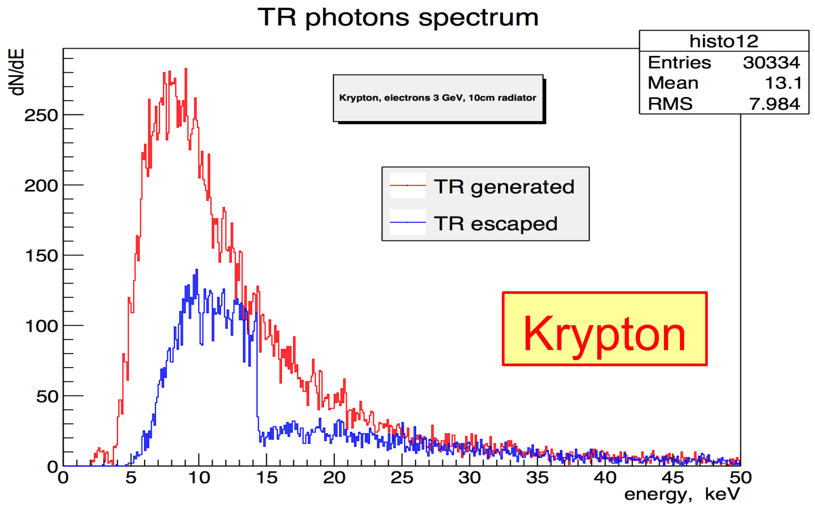


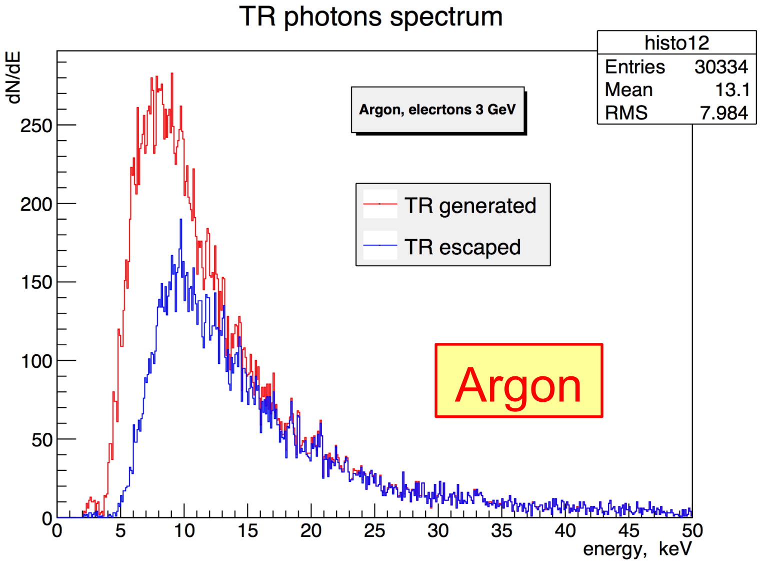
10x10 cm^2

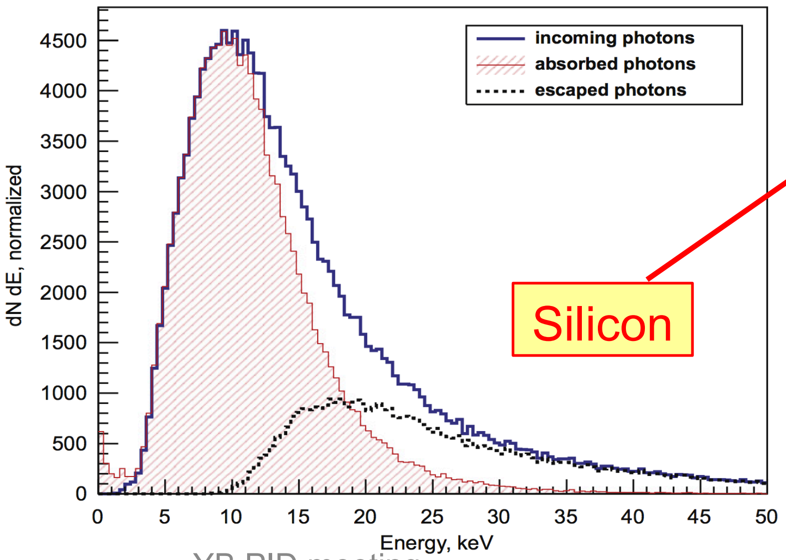
8

TR absorption









New transition radiation detection technique based on DEPFET silicon pixel matrices

https://doi.org/10.1016/j.nima.2010.06.342

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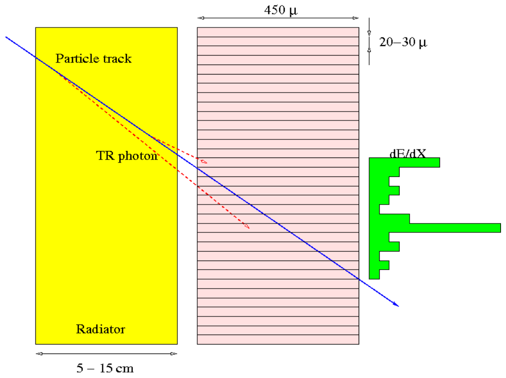
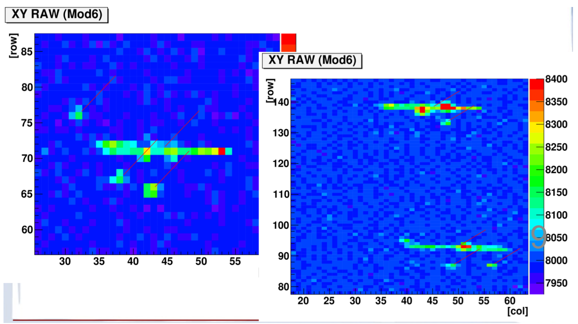
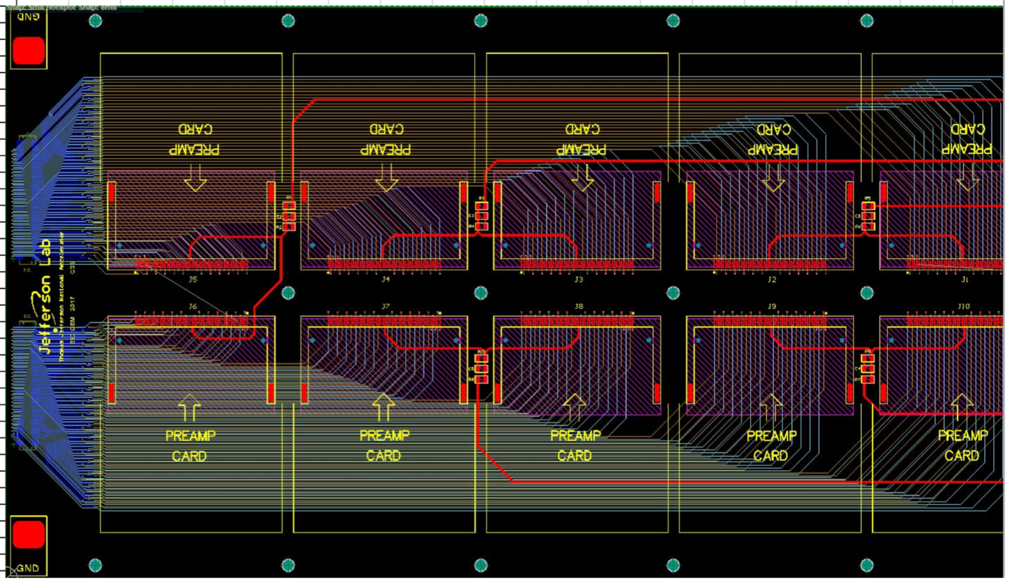
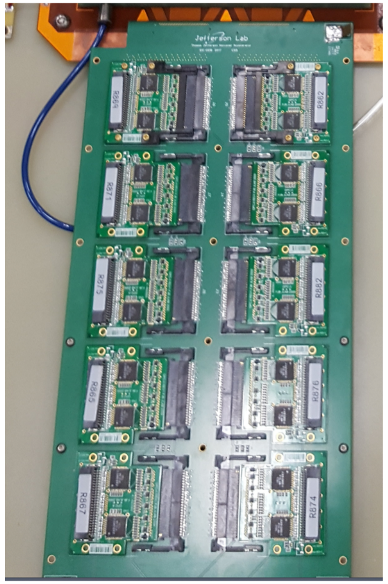


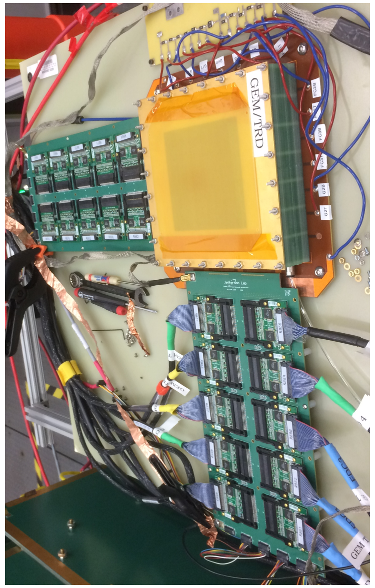


New interface board

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.

HV, GARFIELD and MAGBOLTZ simulation

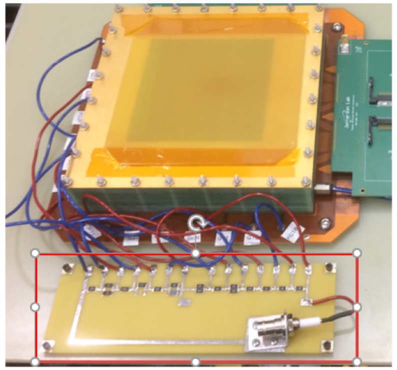
HV divider for GEM-TRD with Gaps 21-2-2-2,

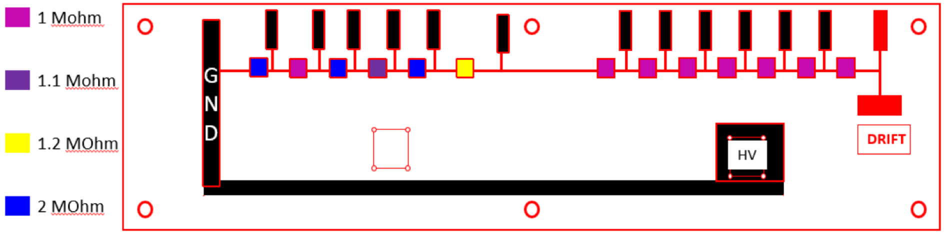
Total divider = 16.3 MΩ

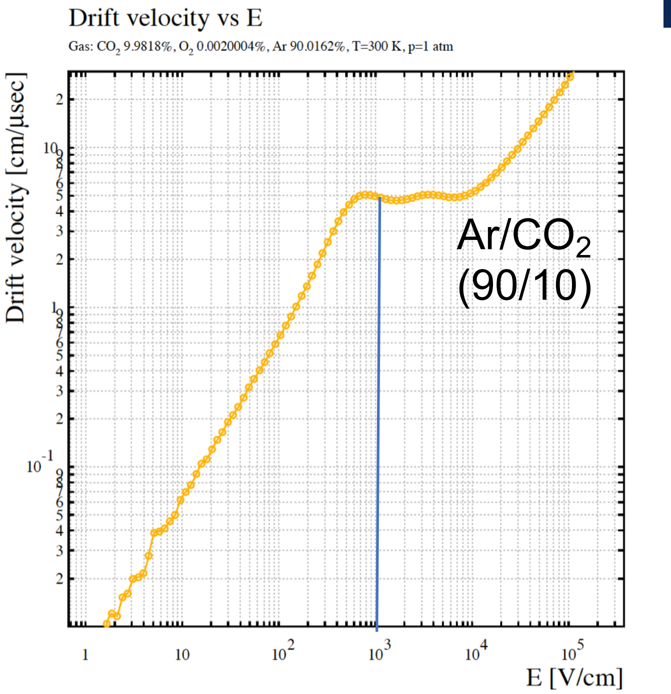
- Amplification divider = 9.3 MΩ
- Drift divider = 7 MΩ

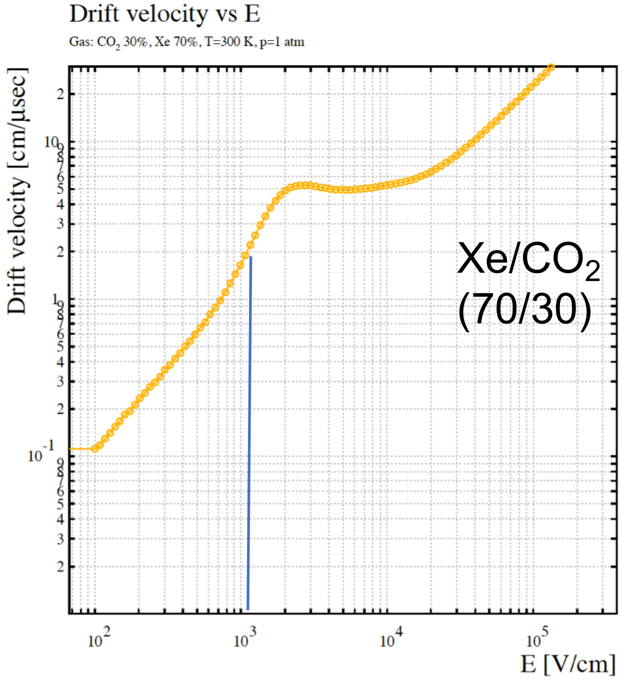
Xe-CO2 1n Hall D ⇨ Operating voltage HV = 6500 V

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

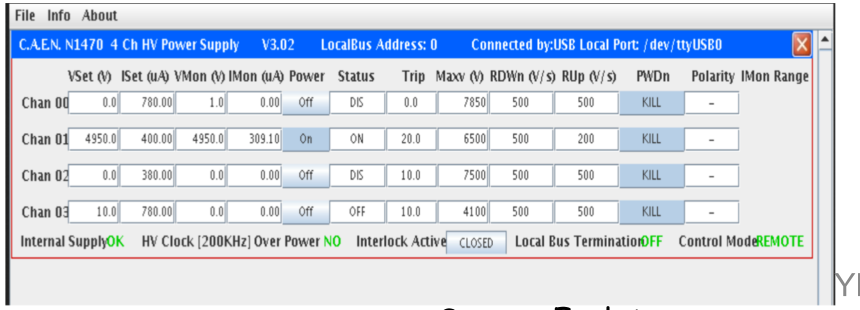




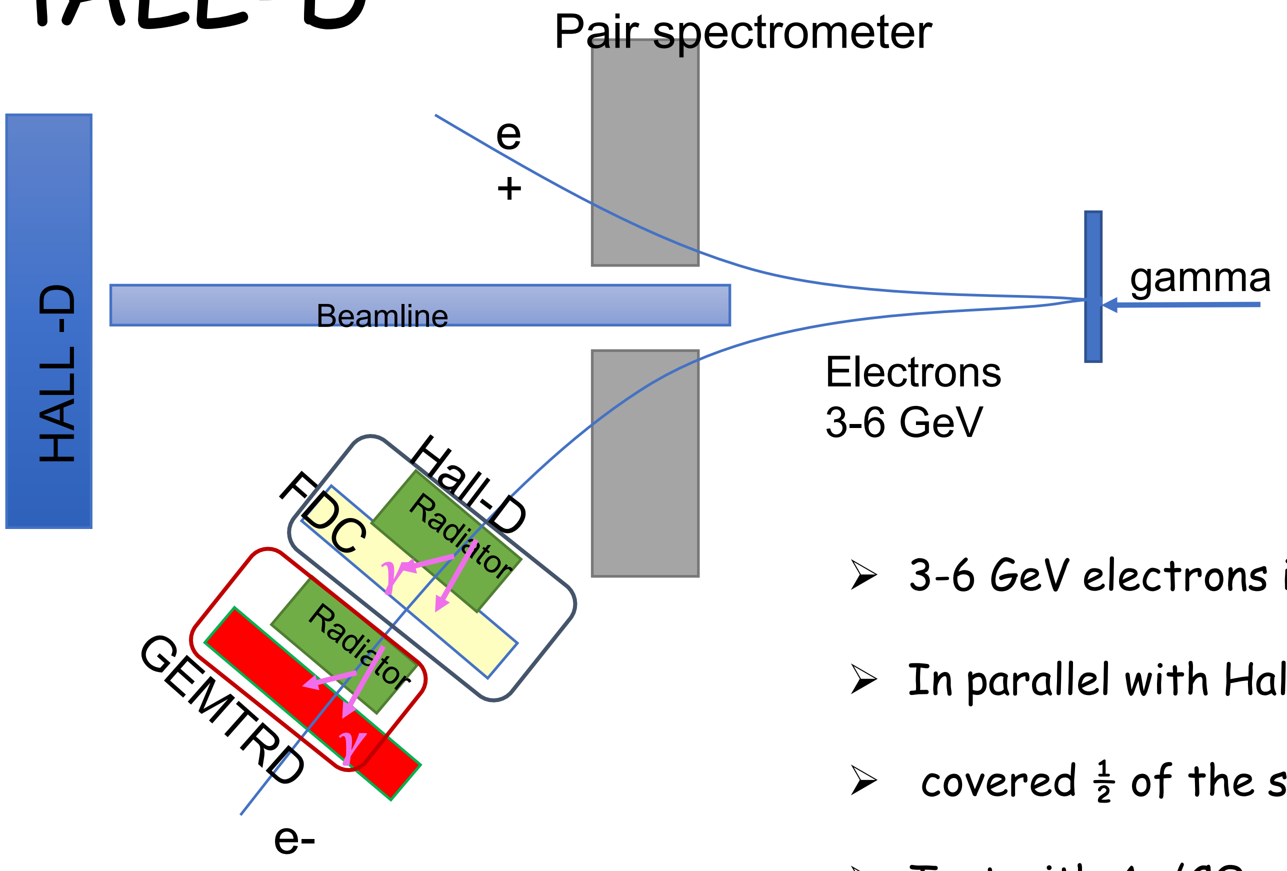


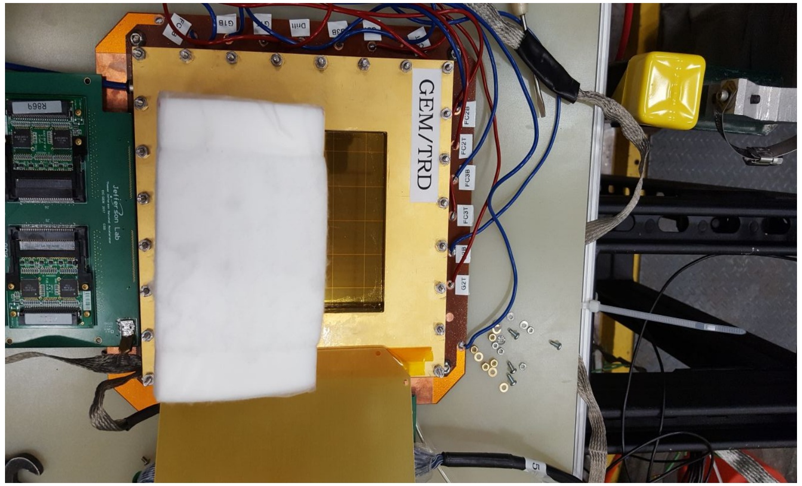


6.5 kV for Xe-CO2, the field in the drift region is 1.33 kV/cm



Test Setup at JLAB HALL-D

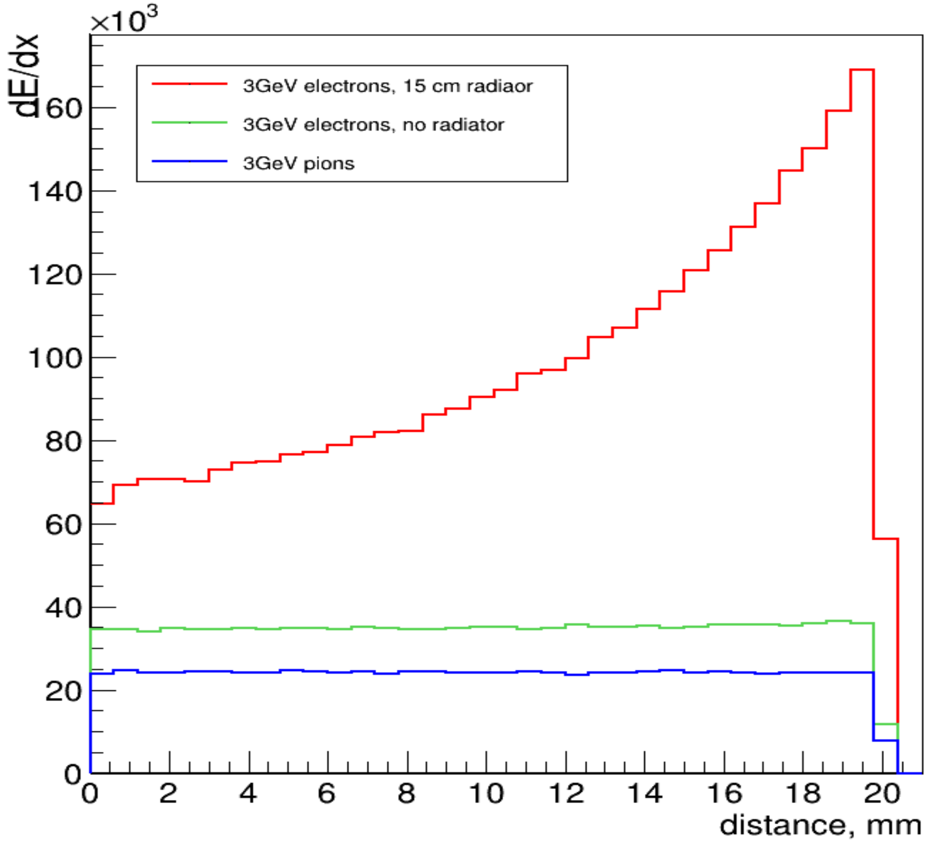


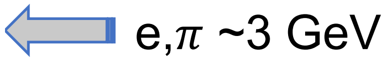


- 3-6 GeV electrons in Hall-D from pair spectrometer
- In parallel with Hall-D MW-TRD (FDC) system
- covered ½ of the sensitive area with radiator (mimicking pion beam)
- Test with Ar/CO_2 and Xe/CO_2 mixtures
- Different radiators

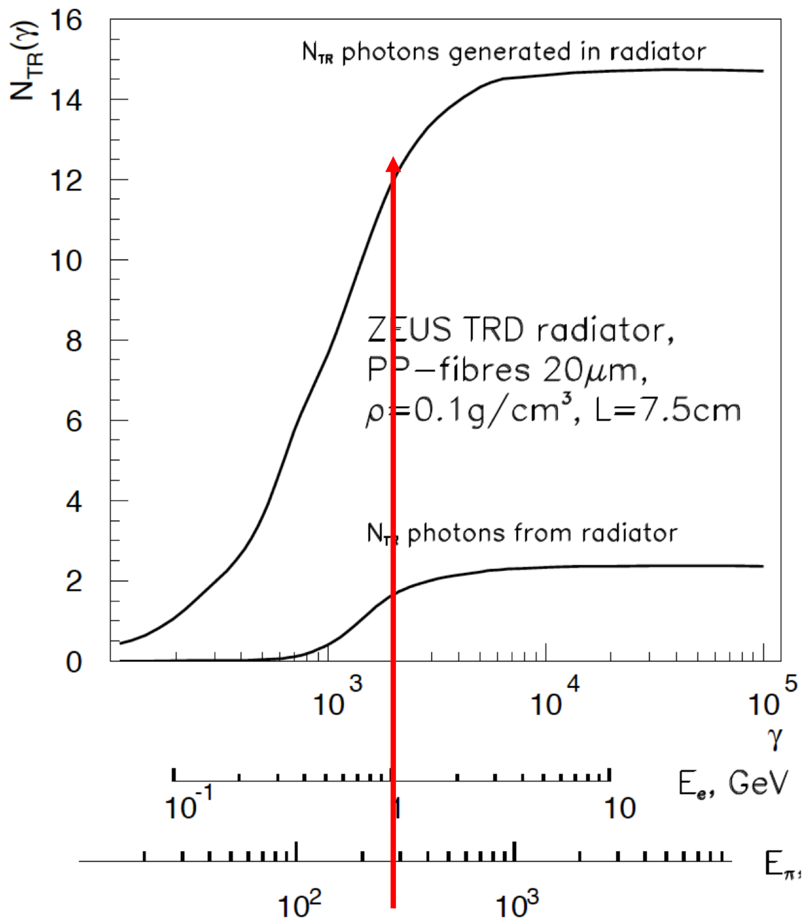
GEANT4: electron and pion comparison

Energy deposition (dE/dx + TR) vs distance





J.Tandler



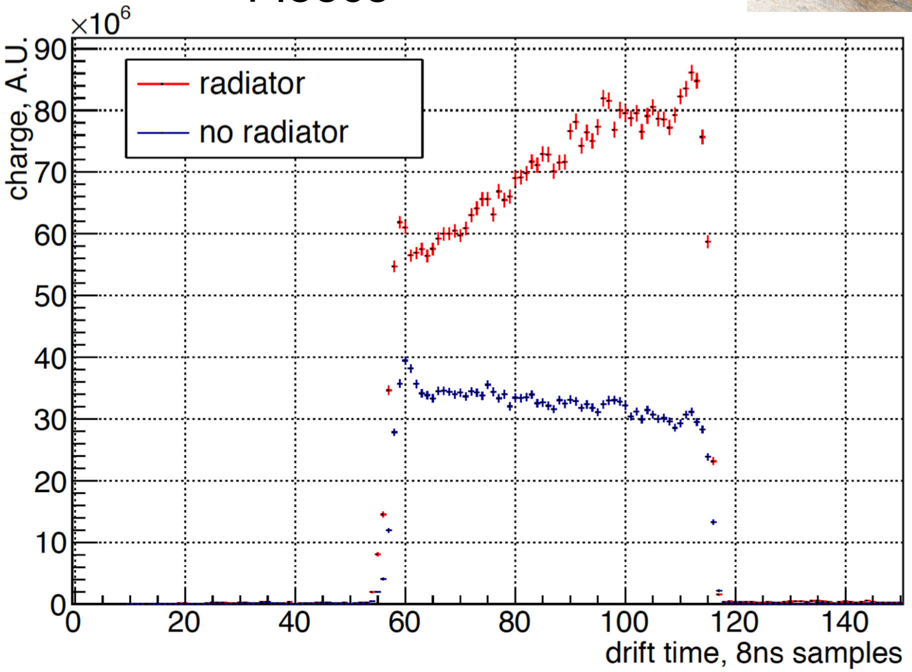
Only e produce TR photons (E>1GeV)
Pions only start to produce TR at E > 100-150 GeV

Charge as a function of drift distance

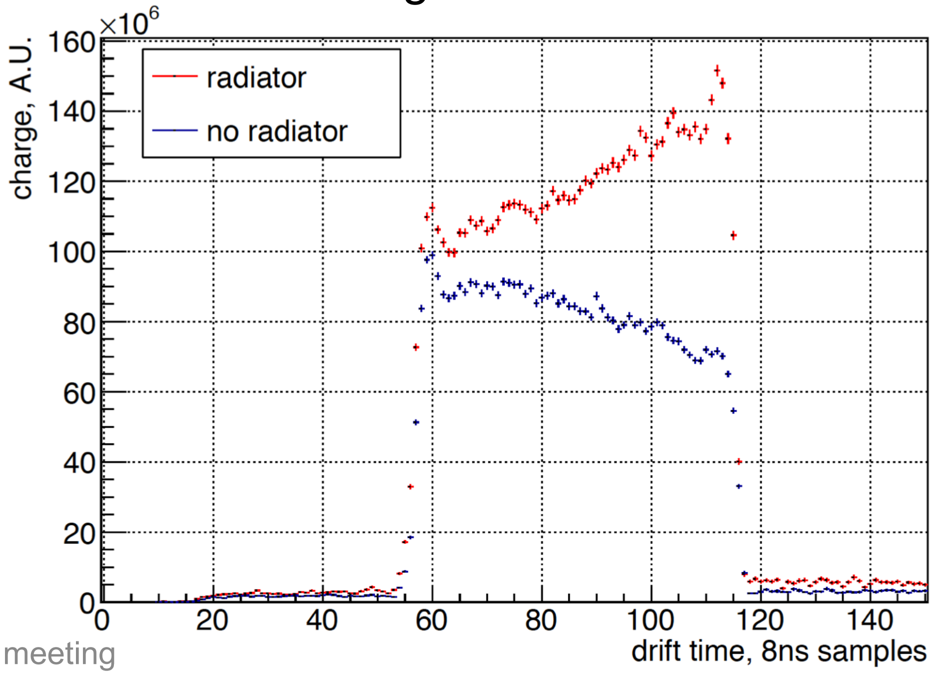
Fleece radiator:
Random oriented
Polypropylene fivers (20μm)

Regular foils:
~200 polypropylene foils (~13 μm thick) with spacers (~180μm) made from nylon net

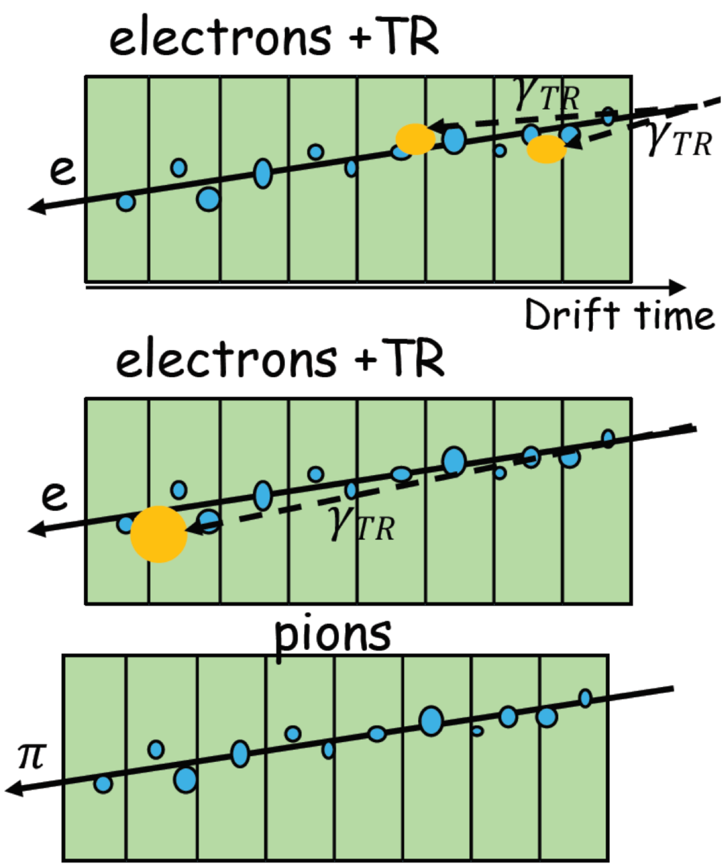
Fleece



Regular foils



GEANT4: electron and pion comparison



Soft TR-photons:

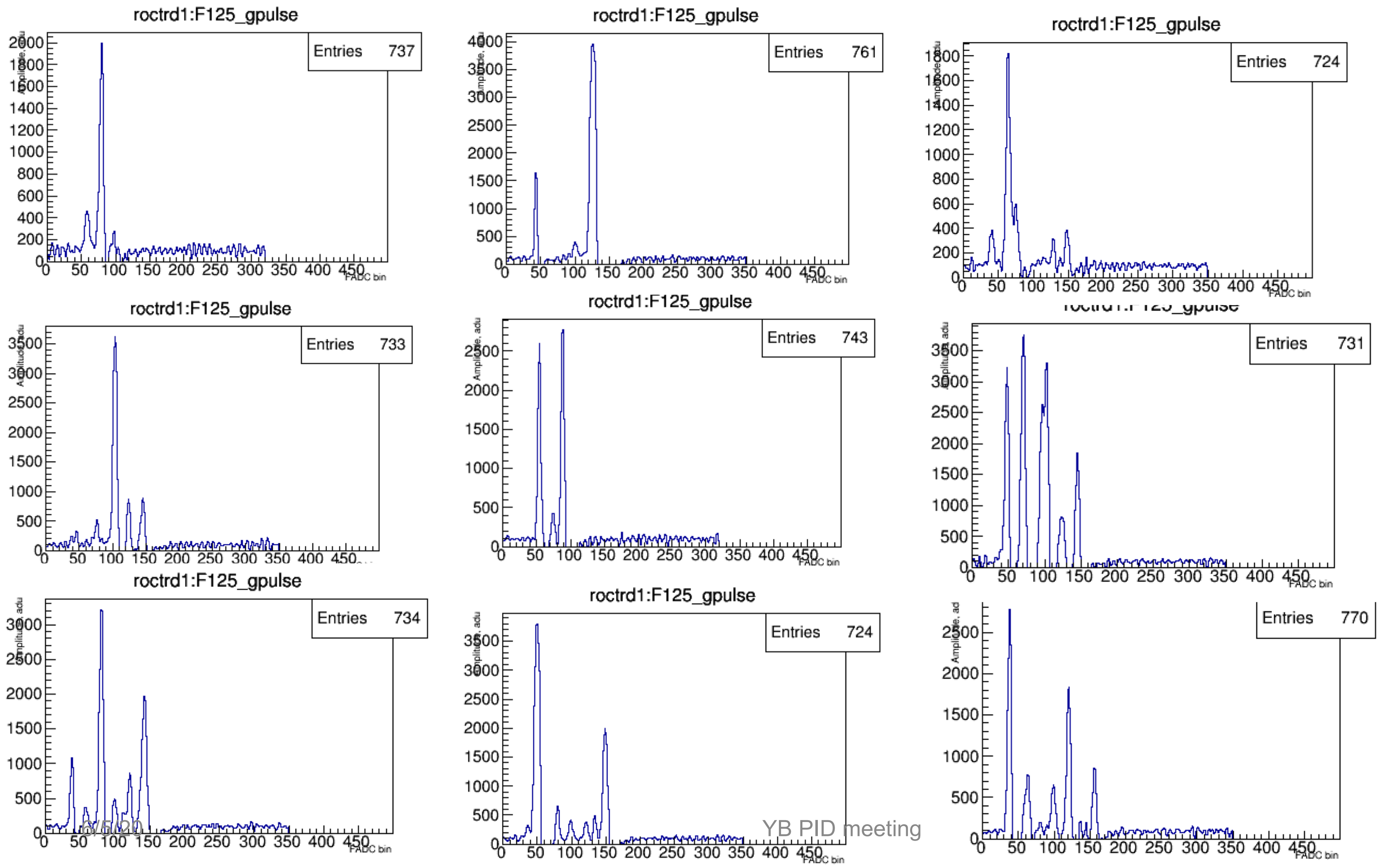
- absorbs near entrance window, therefore have large drift time
- sensitive to dead volumes, like Xe-gap, cathode material.
- Increase of radiator thickness does not lead to increase of number of soft-photons (radiator self-absorption)

Hard TR-photons:

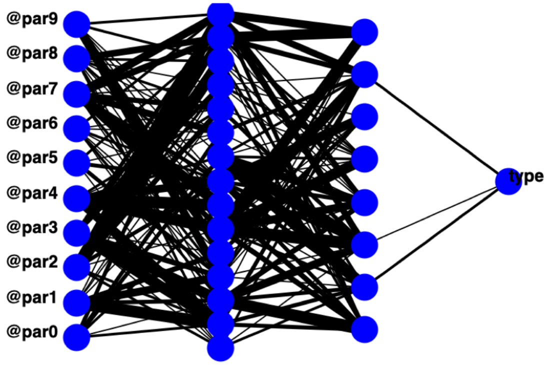
- Depending on energy of TR-photons, could escape detection (depends on detection length)
- Increase of radiator leads to increase of hard TR-spectra.

Separation/ Identification of TR-clusters and dE/dx clusters

Signals from GEMTRD using FlashADC125

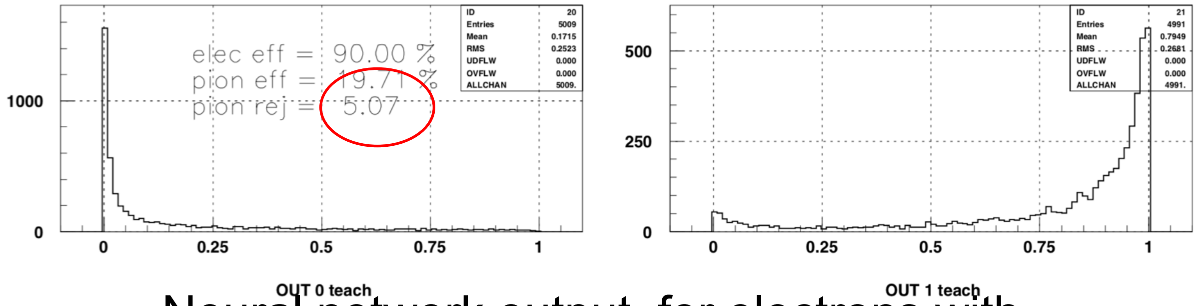


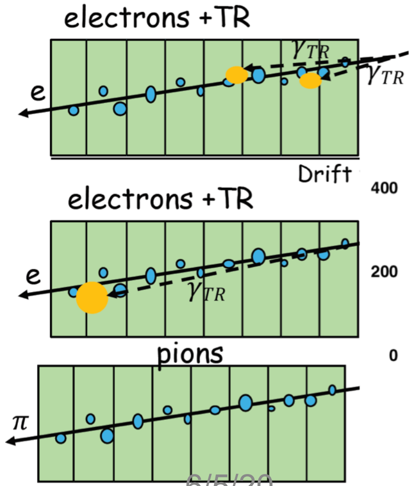
Machine learning technique



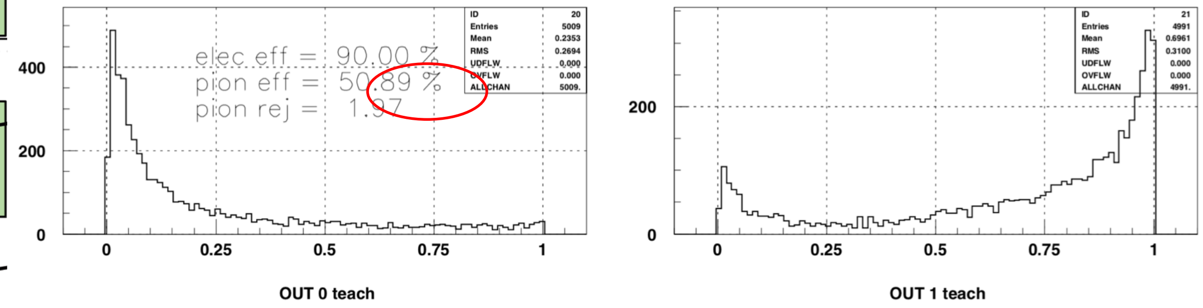
Used different methods/programs (JETNET, Root based-TMVA, etc) for cross-check.

Neural network output for e/π identification



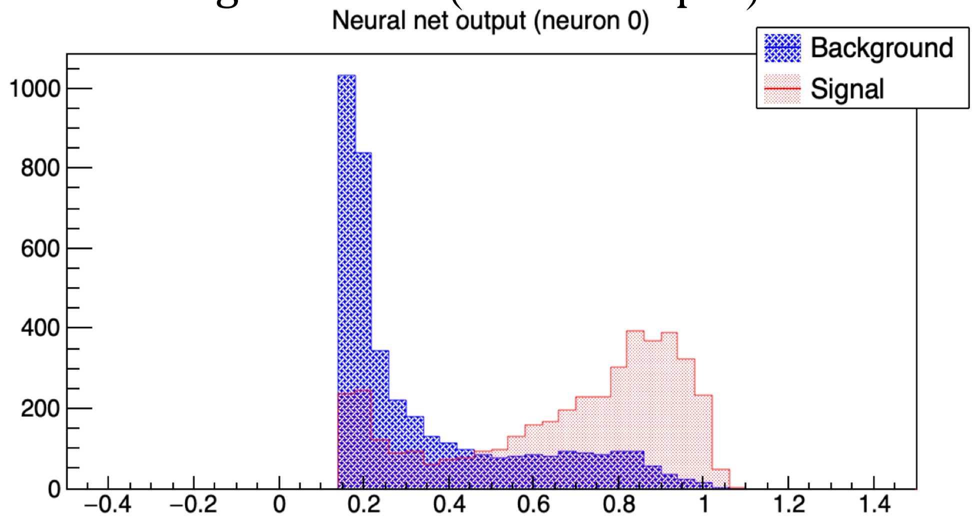


Neural network output for electrons with radiator and without radiator

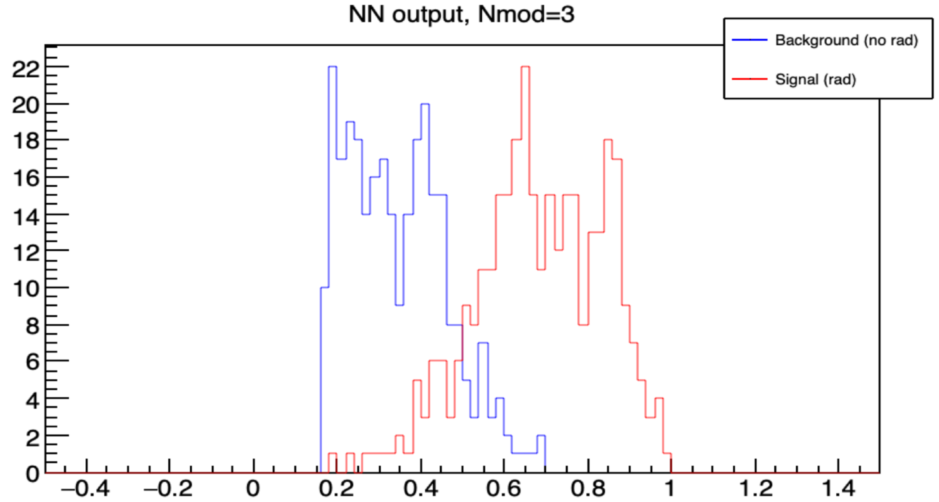


Monte Carlo Sample

Multilayer perceptron output for a single module (DATA sample)



propagation for 3 modules for real data sample

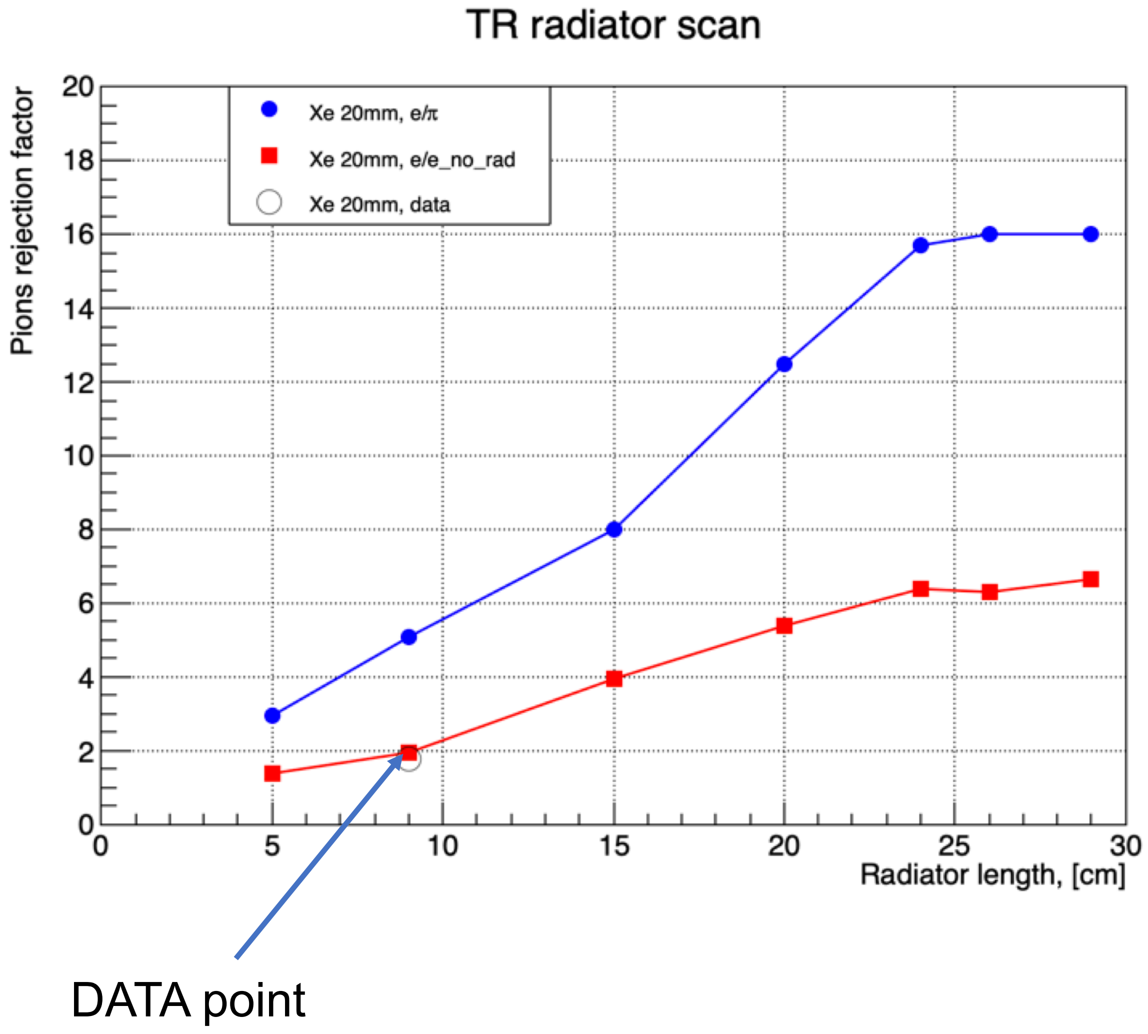


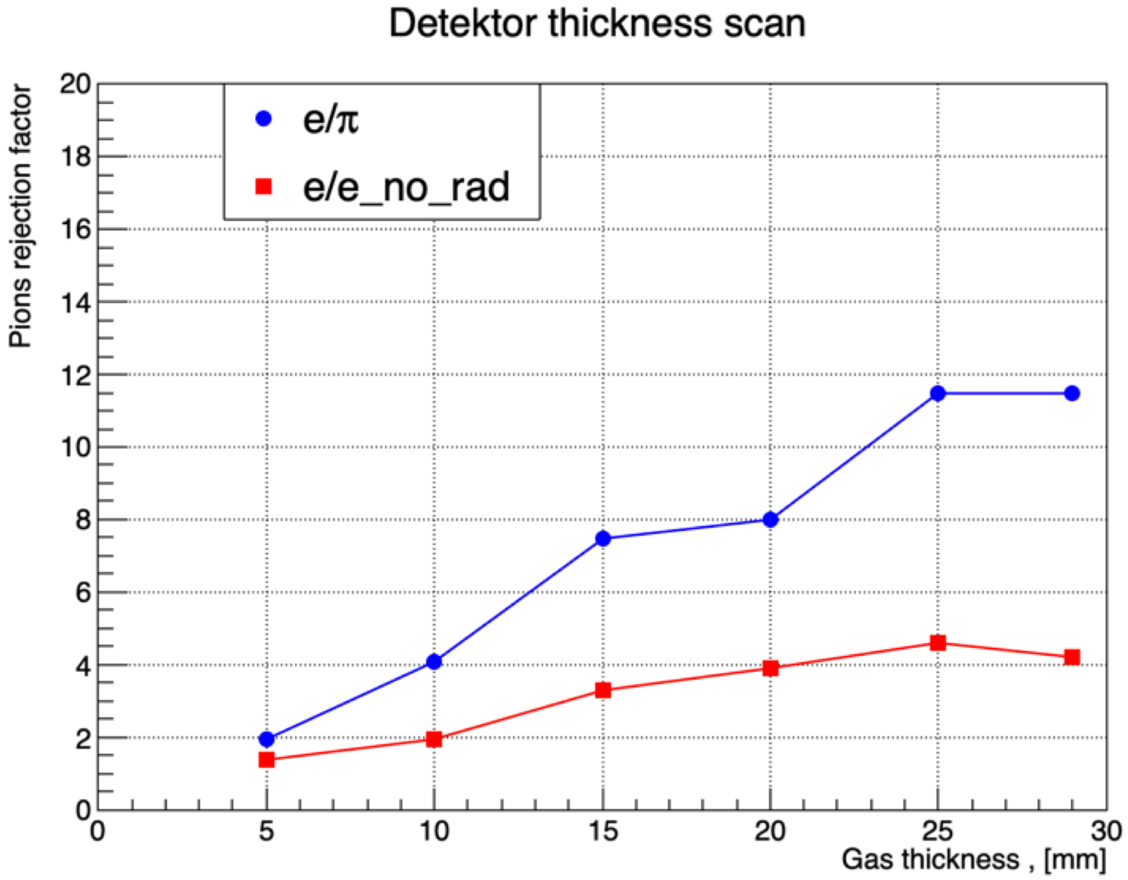
e/π rejectrion

Detector	Dead material in front	Radiator	e/π	$e/e_{no\ radiator}$	$DATA_{e/e_{noR}}$
20 mm	no dead material	20 cm	14.4	6.3	
20 mm	400 μm Xe, Kapton 75μm	20 cm	12.5	5.38	
20 mm	as above	5 cm	2.94	1.37	
20 mm	as above	9 cm	5.07	1.97	1.8
20 mm	as above	15 cm	8.0	3.94	
20 mm	as above	26 cm	16.0	6.3	
20 mm	as above	29 cm	16.1	6.66	
29 mm	400 μm Xe, Kapton 75μm	15 cm	11.5	4.22	
25 mm	as above	15 cm	11.55	4.62	
15 mm	as above	15cm	7.54	3.33	
10 mm	as above	15 cm	4.01	1.97	
5 mm	as above	15 cm	1.96	1.38	

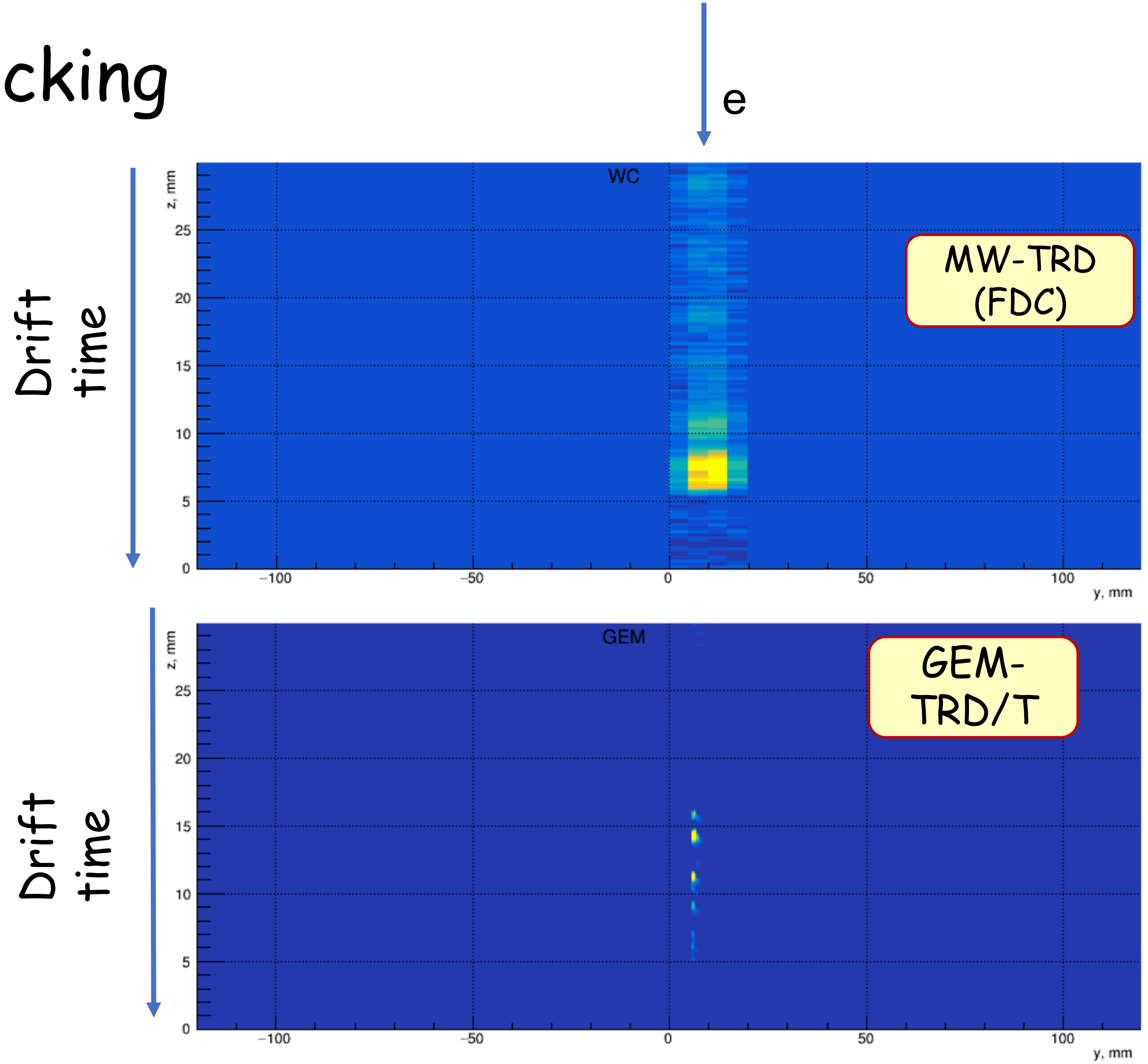
Table 1: Rejection factor corresponding to 90% of electron efficiency

e/π rejection (MC and Data)





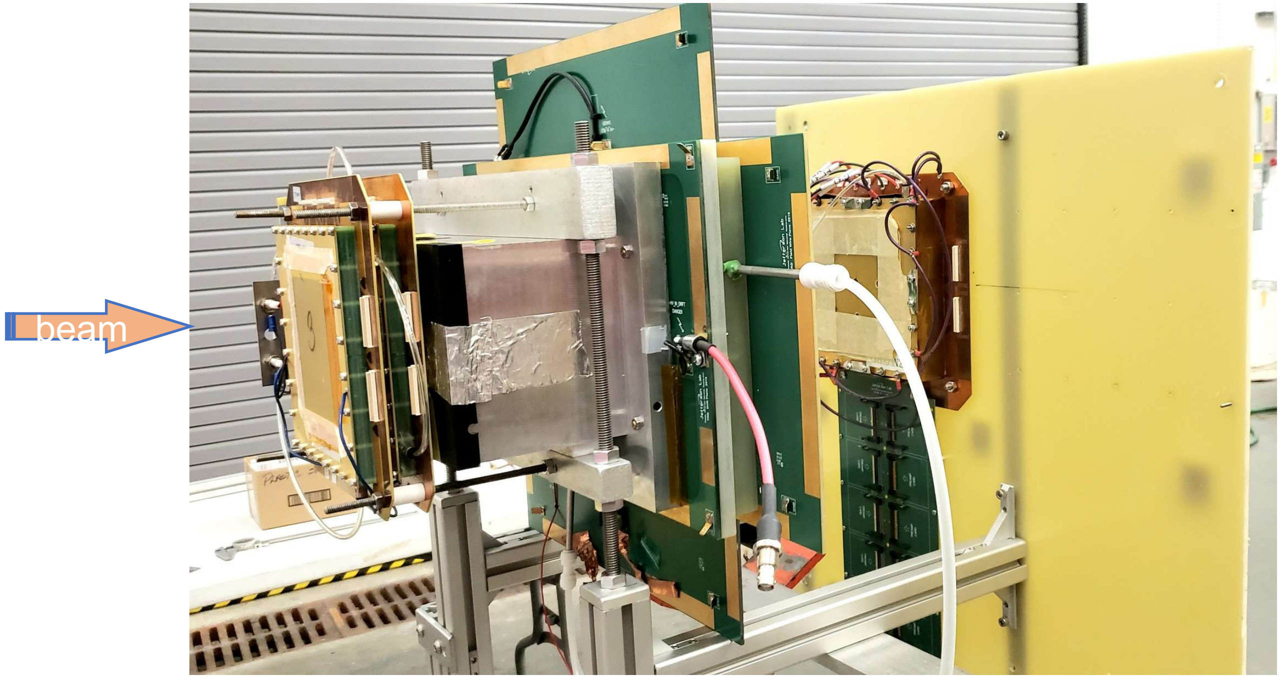
Tracking

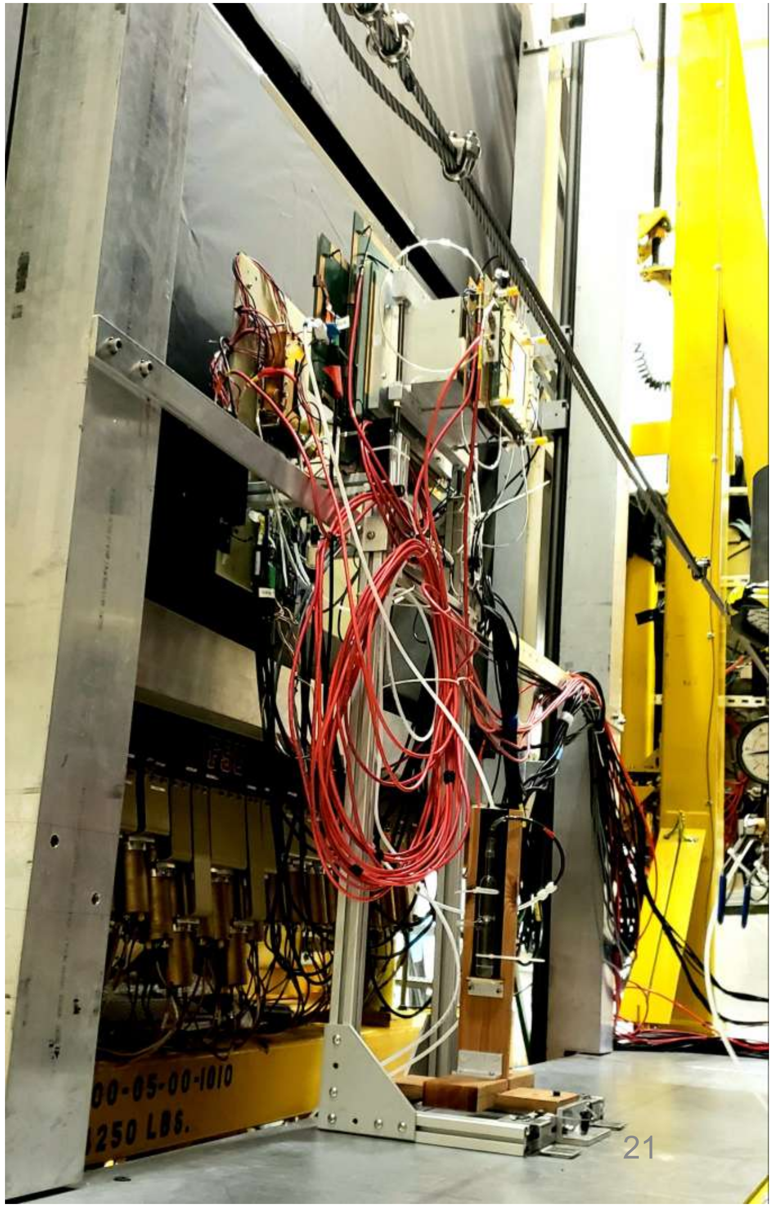


GEMTRD/T provides a tack segment ($\mu TPC\ mode$)

GEMTRD test setup with GlueX

- **Motivation:**
- To check for real e/pi rejection (detector response on pions)
- Also important for DIRC (precise tracking in front of the detector)



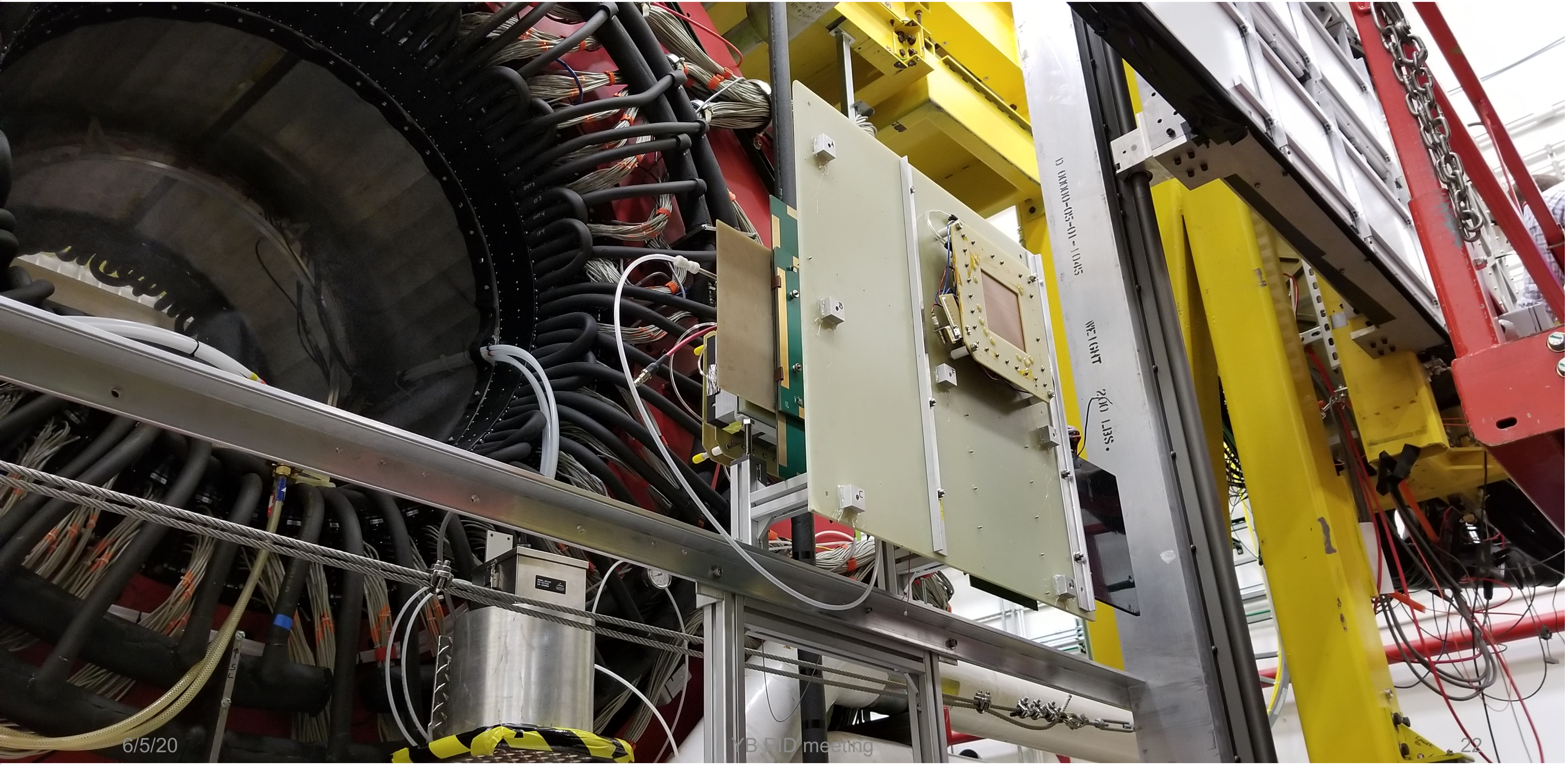


- Setup: 5 tracking detectors

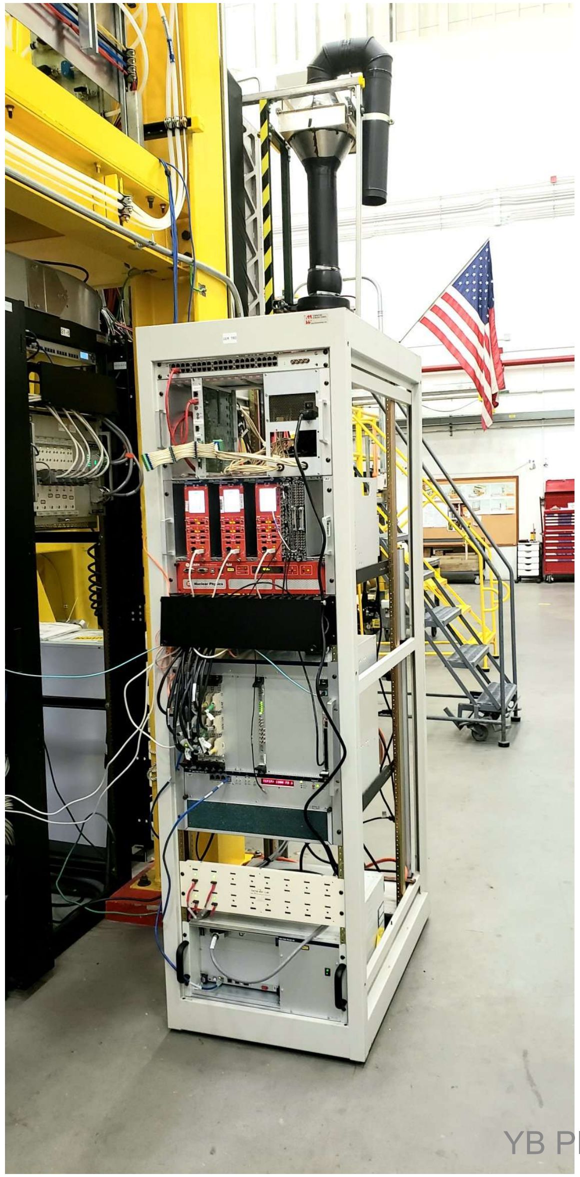
Counting from the target:

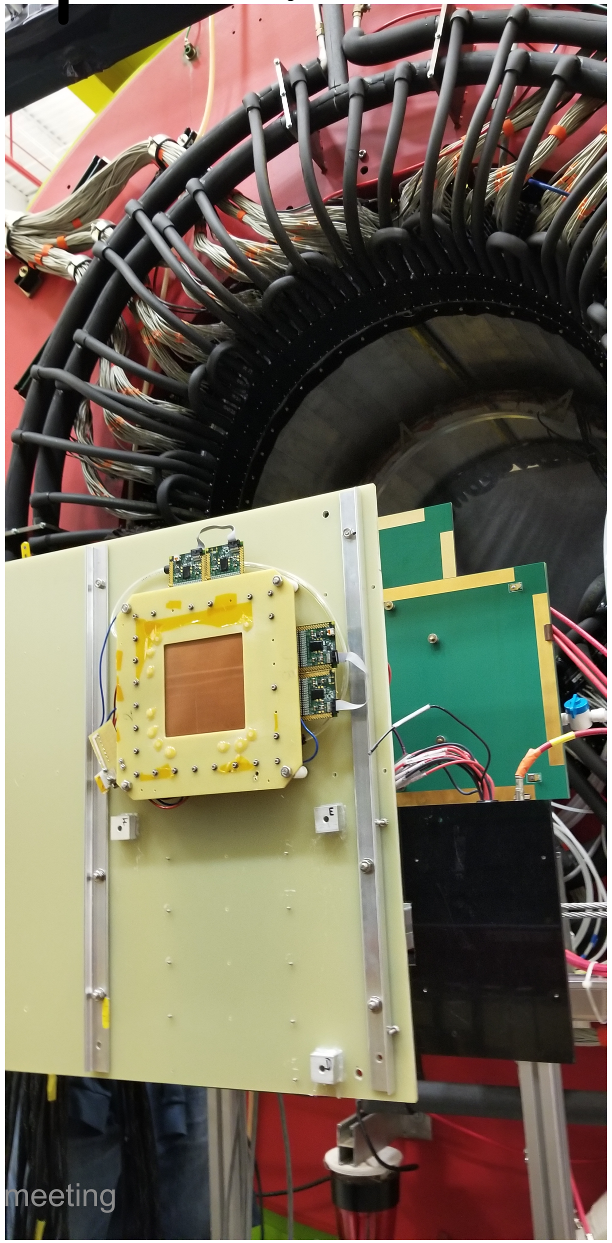
-Standard GEM, uRWELL, TRD Multi wire chamber (TRD-MW), GEM-TRD, Standard GEM plane.

GEMTRD setup at the GlueX experiment



Integration into GlueX experiment





Machine learning technique on FPGA

On-line particle identification:

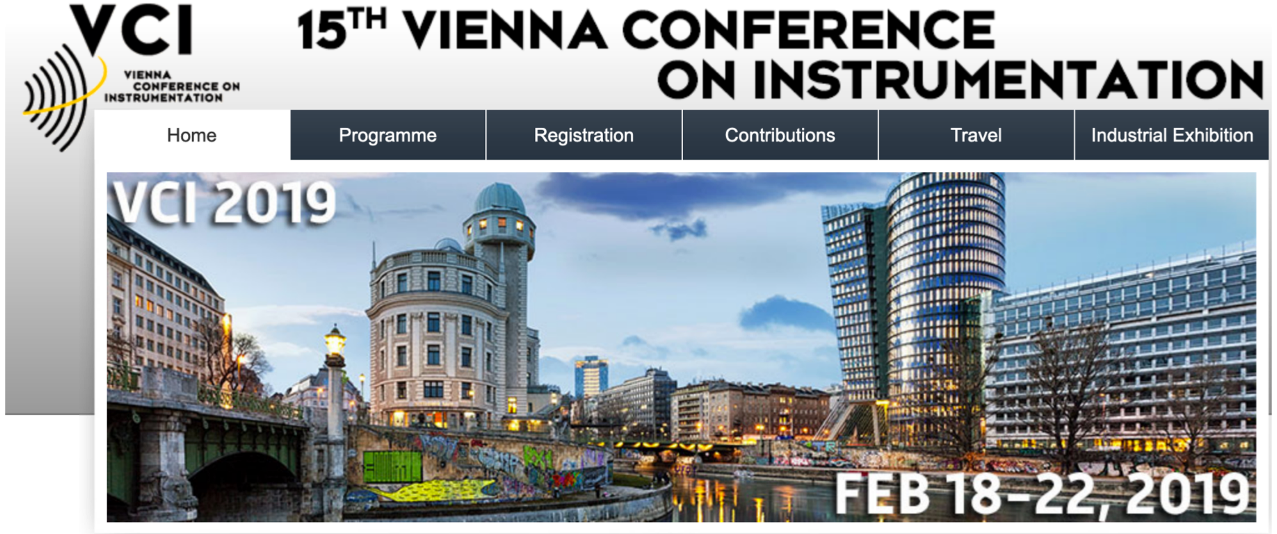
- ✓ move a part of an off-line reconstruction software into on-line (FPGA).
- ✓ This is a collaborative effort with Hall-D (GlueX) experiment and ODU (engineering department)
- ✓ Could be applied for single detector as well as for GLOBAL PID (dE/dx, Cherenkov det, calorimeters, TOF, TRD…)

Step1.
-> Optimize software on computer,
-> Compare with other likelihood methods
-> adopt this technique for a possible use within the FPGA

Step2. FPGA (VIRTEX) ordered (expecting delivery in January)

Step3. Code algorithm for FPGA

Conferences



A new Transition Radiation detector based on GEM technology
https://doi.org/10.1016/j.nima.2019.162356

Conclusions

- Very challenging!