eRD22: GEM based Transition radiation detector/tracker for EIC

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

GEM-TRD/T TEAM:

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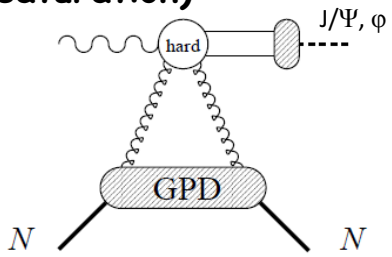
  - ✓ Lubomir Pentchev
  - ✓ Beni Zihlmann
  - ✓ Chris Stanislav
  - ✓ Fernando Barbosa
- University of Virginia
  - ✓ Kondo Gnanvo
  - ✓ Nilanga K. Liyanage
- Temple University
  - ✓ Matt Posik
  - ✓ Bernd Surrow

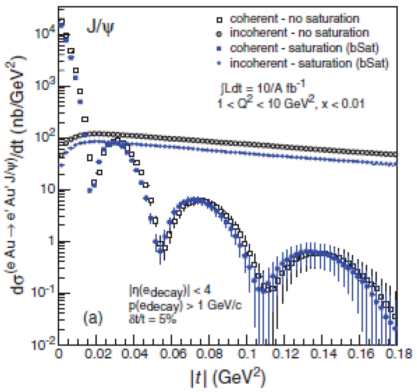
Electron identification (e/hadron separation)

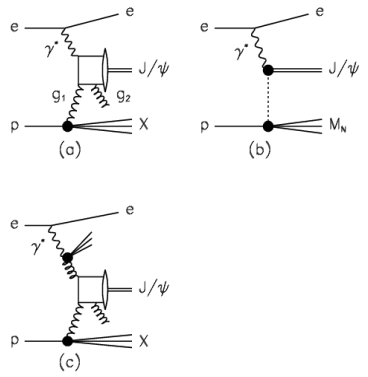
- **GPD and Coherent Exclusive Diffraction (saturation)**



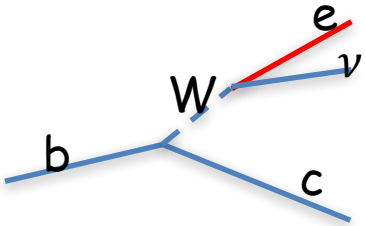
Br (J/ψ->e+e-) ~6%

Br (J/ψ->μ+μ-) ~6%



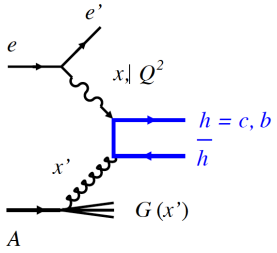


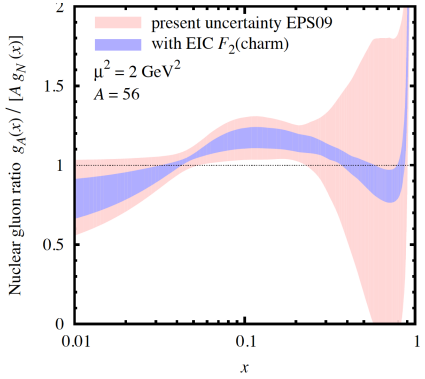
- **Heavy quark tagging**



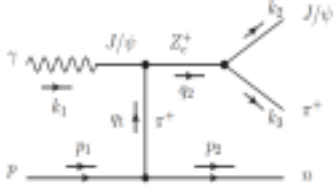
Br ($D^{\pm}$->e+X) ~16%

Br ($B^{\pm}$->e+ν+X_c) ~10%



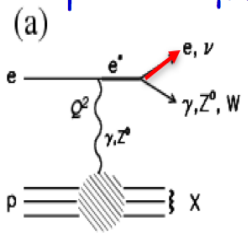


- **Exotic spectroscopy (pentaquarks, tetraquarks, XYZ)**

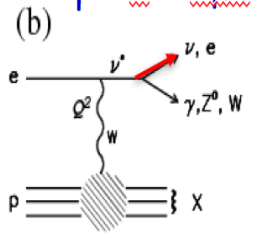


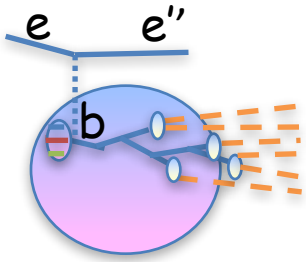
- **Other BSM physics**

ep-> e*-> eγX

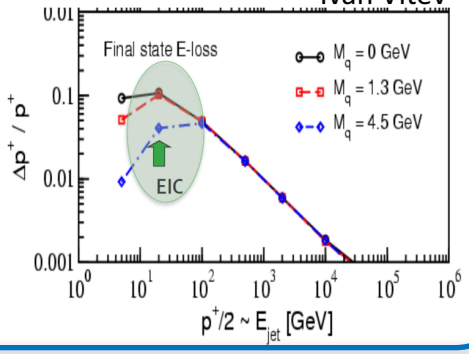


ep-> ν*->νγX





Ivan Vitev

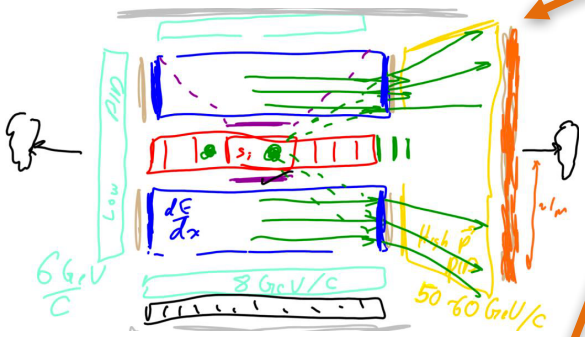


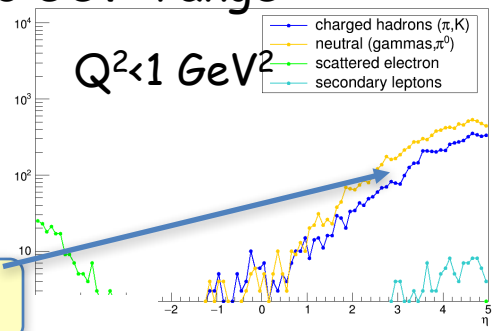
Electron/hadron separation

- 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

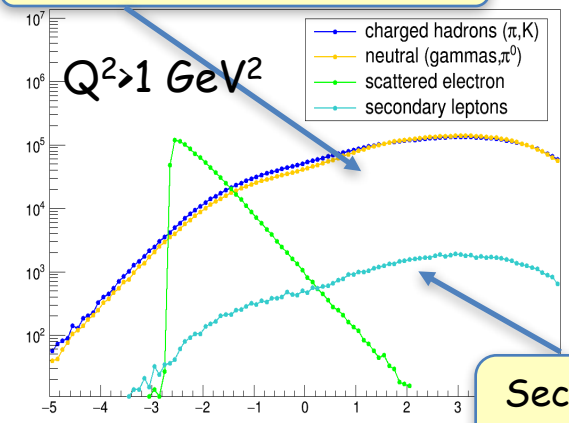
- Hadron end-cap
- between dRICH and EMCAL (extra tracking point)

GEM-TRD/T

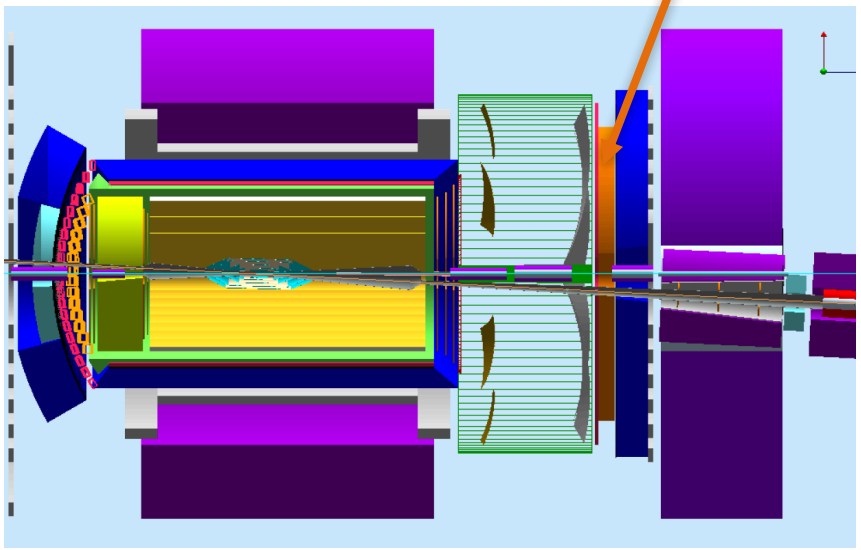




High hadron background



Secondary electrons, pt>100MeV



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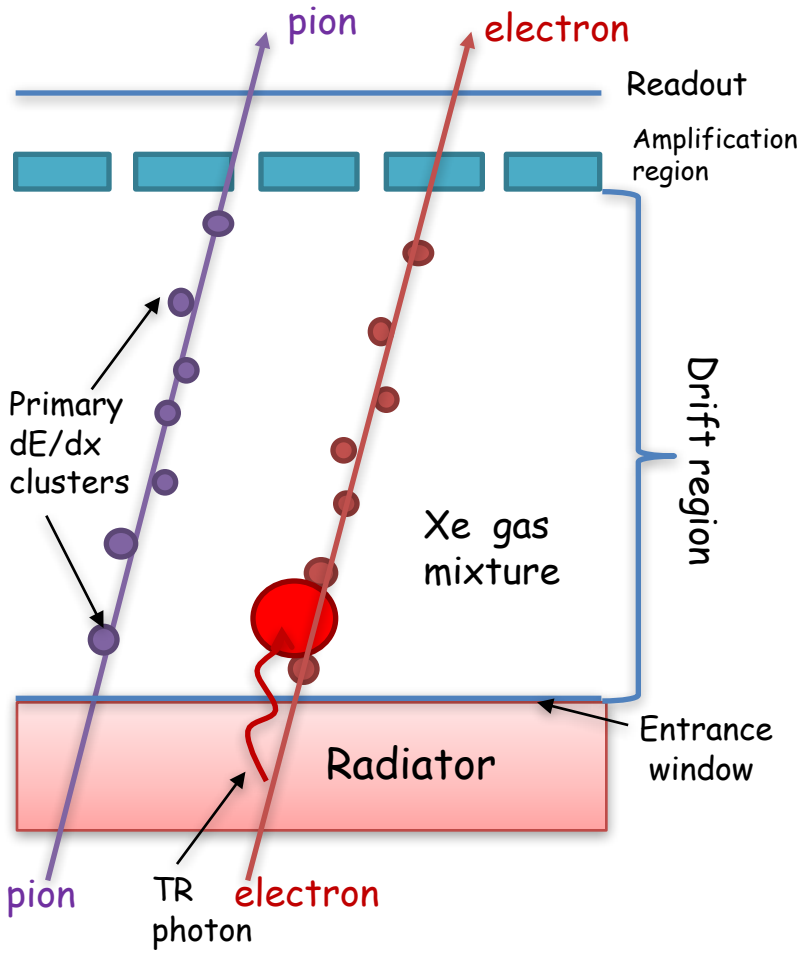
GEM as Transition Radiation detector and tracker for EIC

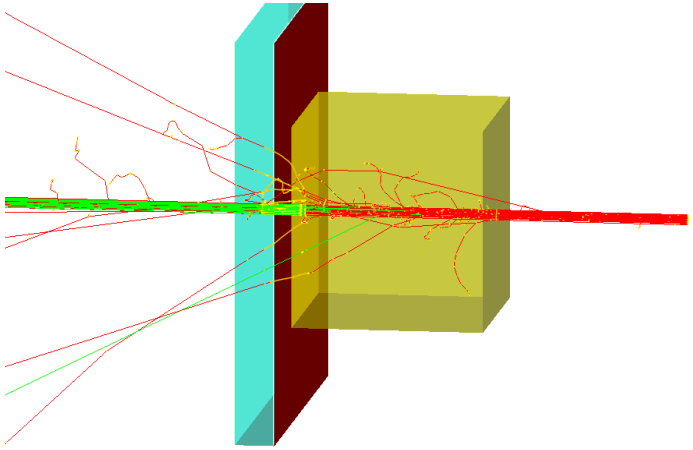
- High resolution tracker.
- Low material budget detector
- How to convert GEM tracker to TRD:
  - ✓ Change gas mixture from Argon to Xenon (TRD uses a heavy gas for efficient absorption of X-rays)
  - ✓ Increase drift region up to 2-3 cm (for the same reason).
  - ✓ Add a radiator in the front of each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

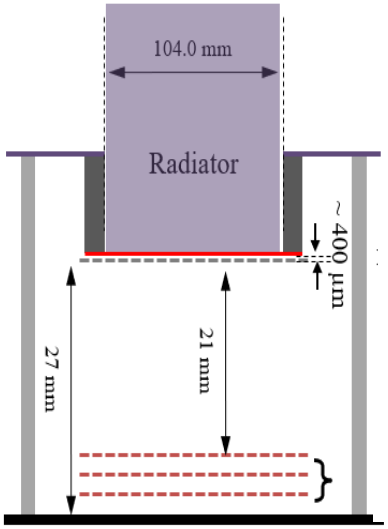


GEANT4: electron and pion comparison

Parameters:

- ✓ Detector Gas Volume (D) : 1 – 4 cm
- ✓ Radiator Volume (R): 3-10 cm
- ✓ "Dead region":
  - ✓ cathode material(Al, Cu, Cr)
  - ✓ gap (Xe filled) 400um
- ✓ Gas mixture: Xe/CO_2 , Ar/CO_2 …
- ✓ # layers:1,2,3 …



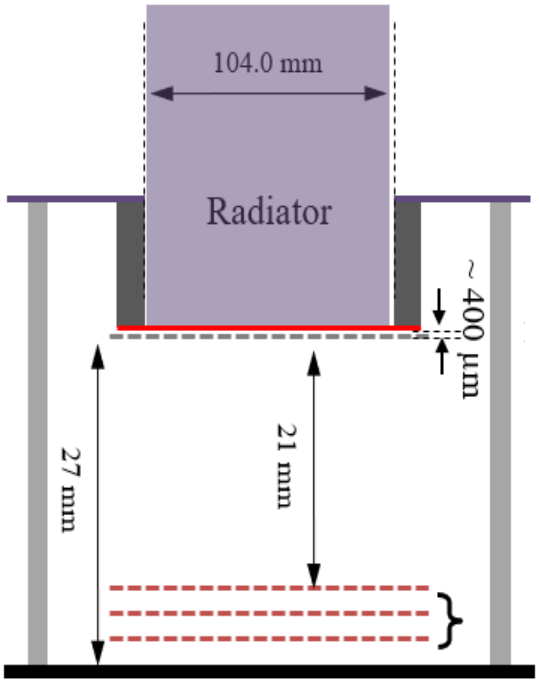


Cathode

3 GEM foils

GEM-TRD/T prototype

- A standard Cu-GEM-TRD/T prototype is currently under tests
- A new Cr-GEM-TRD/T prototype is under assembly at UVA, will be installed at test beam during the next run.



Cr-Cathode

3 Cr-GEM foils

UVa Cr-GEM-TRD

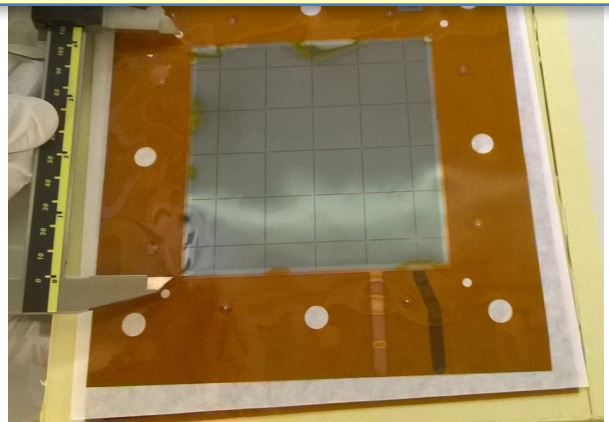
Triple-GEM with standard 5μm Cu-GEM foil

	Quantity	Thickness μm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	5.2	8.96	14.3	0.8	0.0291	0.0037
Kapton	1	50	1.42	286	0.8	0.0140	0.0057
GEM Foil							
Copper	6	5.2	8.96	14.3	0.8	0.1745	0.0224
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	5.2	8.96	14.3	0.2	0.0073	0.0009
Copper-350	1	5.2	8.96	14.3	0.85	0.0309	0.0040
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO2)	1	15000	1.84E-03	18310	1	0.0819	0.0028
					Total	0.473	0.089

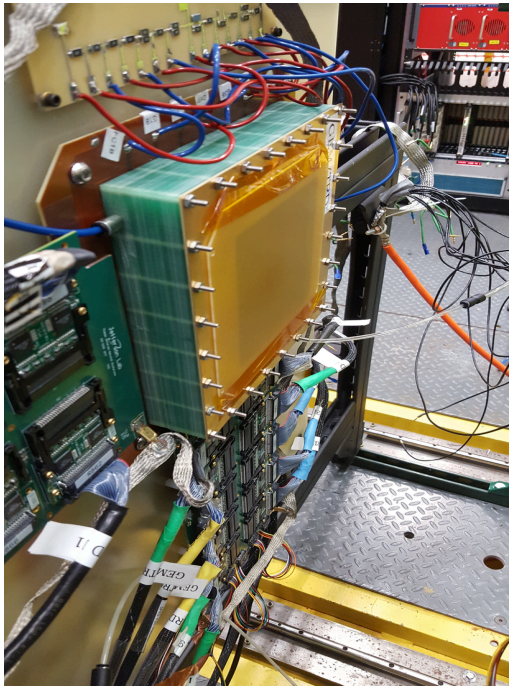
Triple-GEM with Cr-GEM foil

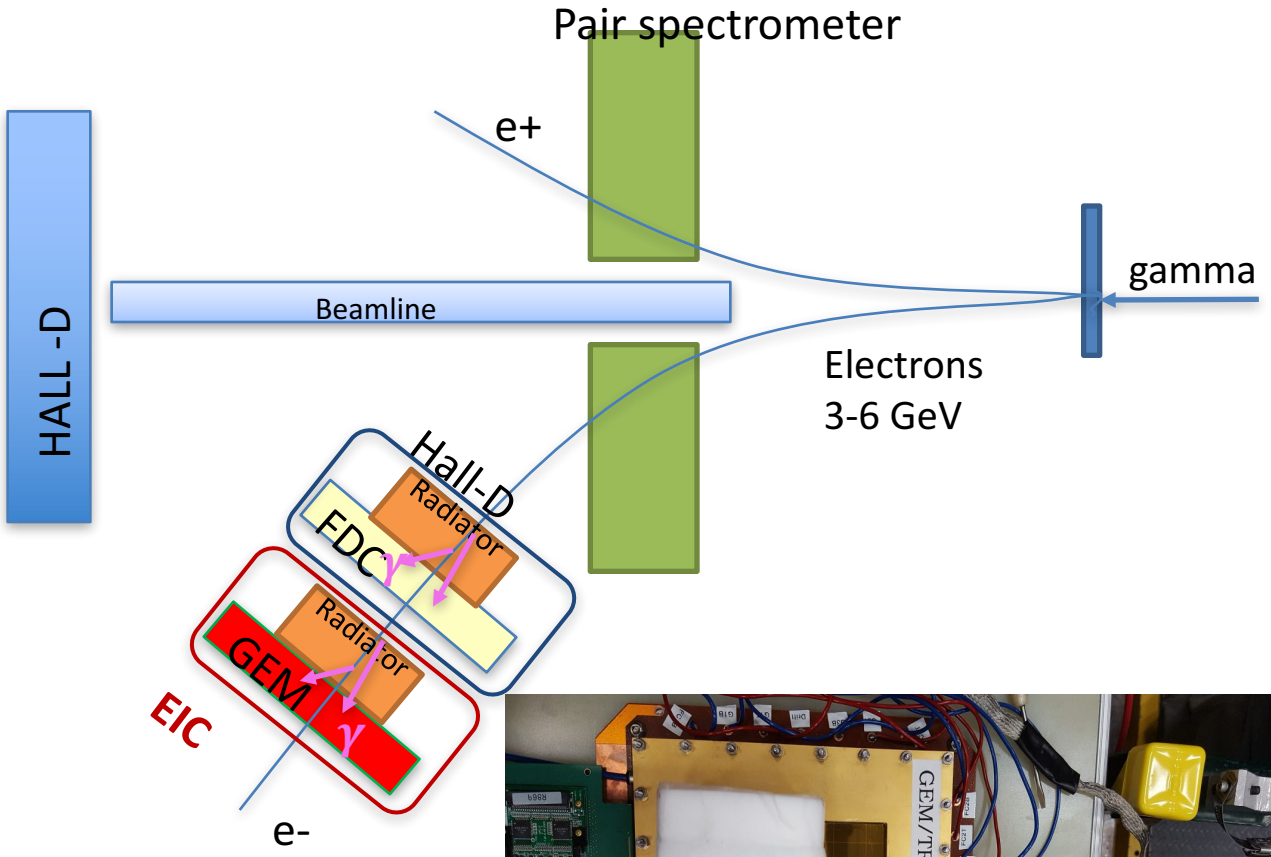
	Quantity	Thickness μm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	0.2	8.96	14.3	0.8	0.0011	0.0001
Kapton	1	50	1.42	286	0.8	0.0140	0.0057
GEM Foil							
Copper	6	0.2	8.96	14.3	0.8	0.0067	0.0009
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	0.2	8.96	14.3	0.2	0.0003	0.0000
Copper-350	1	0.2	8.96	14.3	0.85	0.0012	0.0002
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO2)	1	15000	1.84E-03	18310	1	0.0819	0.0028
					Total	0.240	0.059

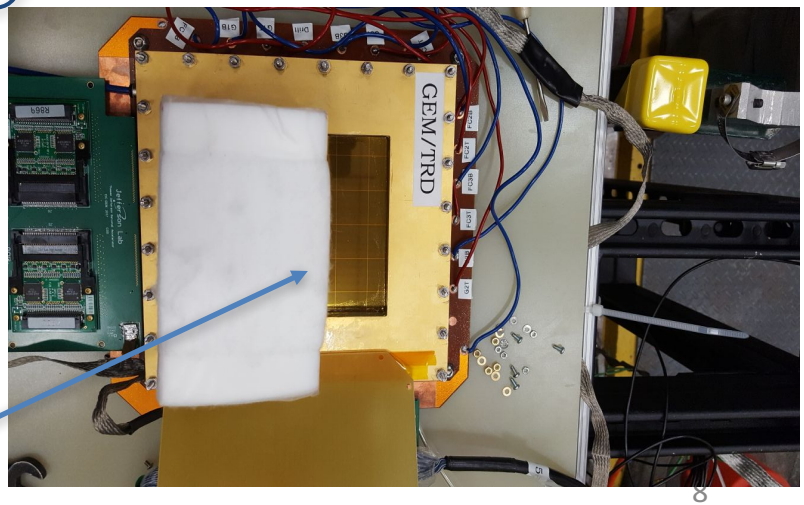
~50% reduction in the amount of material with Cr-GEM



Test Setup at JLAB HALL-D



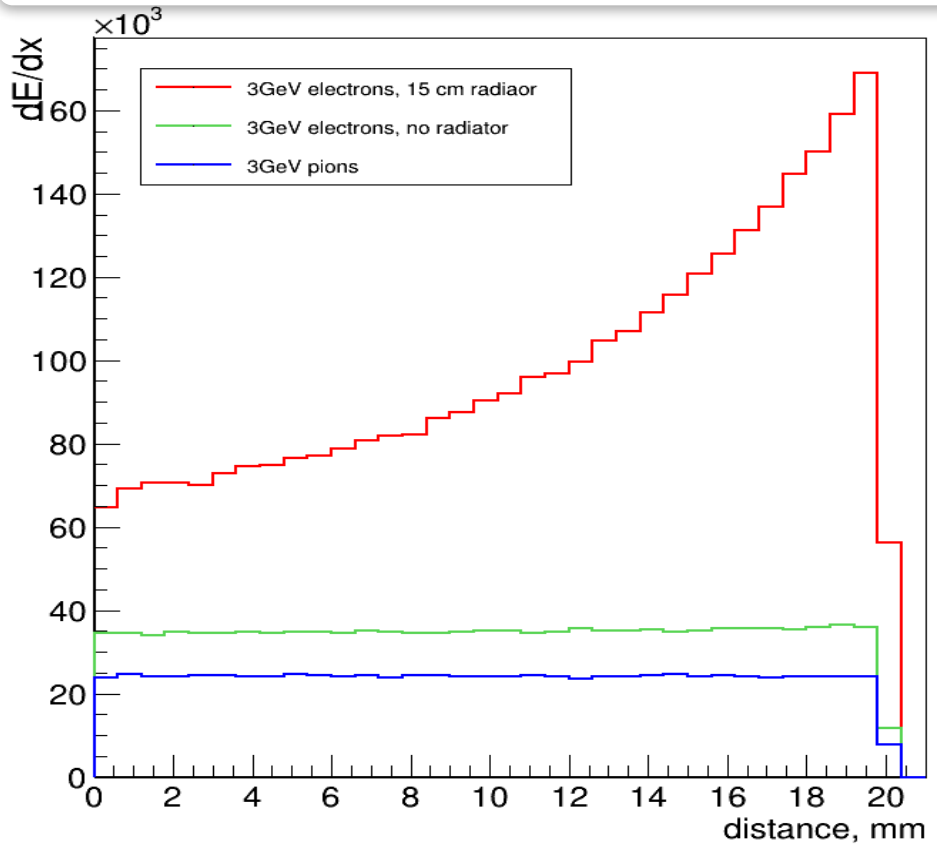




- 3-6 GeV electrons in Hall-D from pair spectrometer
- In parallel with Hall-D MW-TRD (FDC) system
- covered ½ of the sensitive area with radiator

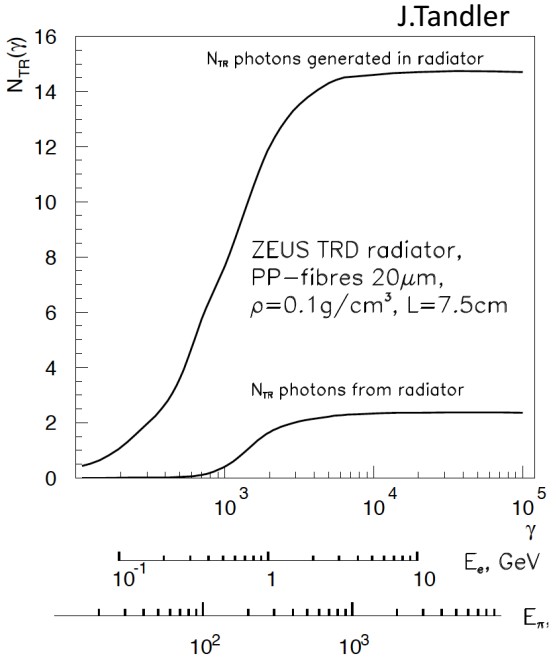
GEANT4: electron and pion comparison

Energy deposition (dE/dx + TR) vs distance

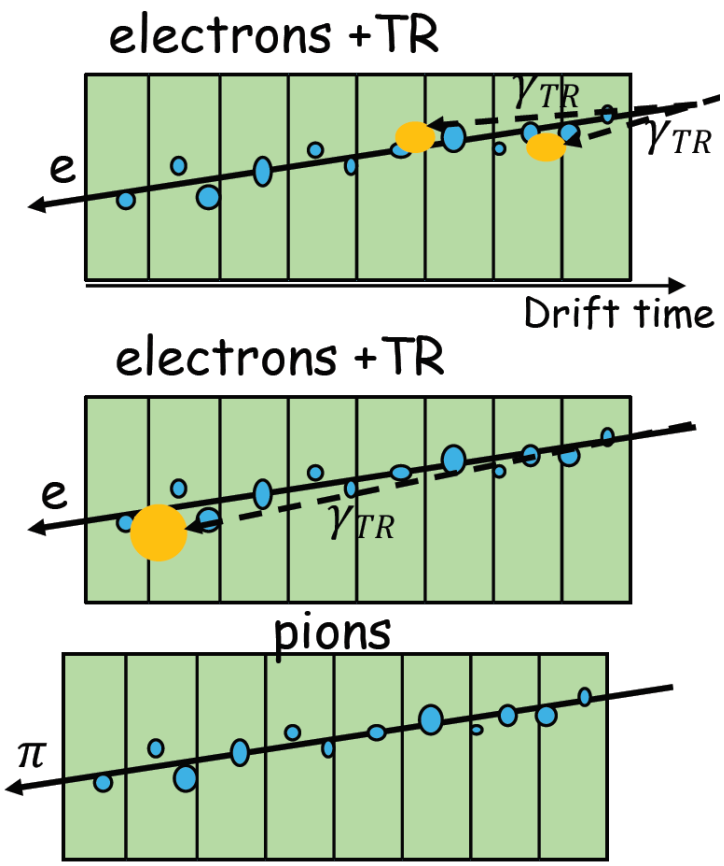


e,π ~3 GeV

J.Tandler



GEANT4: electron and pion comparison



Soft TR-photons:

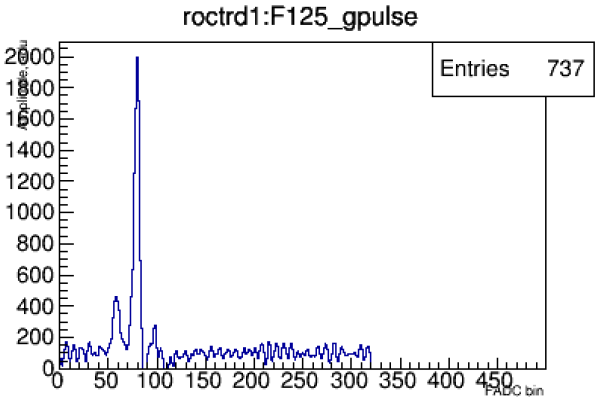
- absorbs near entrance window, therefore have large drift time
- sensitive to dead volumes, like Xe-gap, cathode material.
- Increase of radiator thickness does not lead to increase of number of soft-photons (radiator self-absorption)

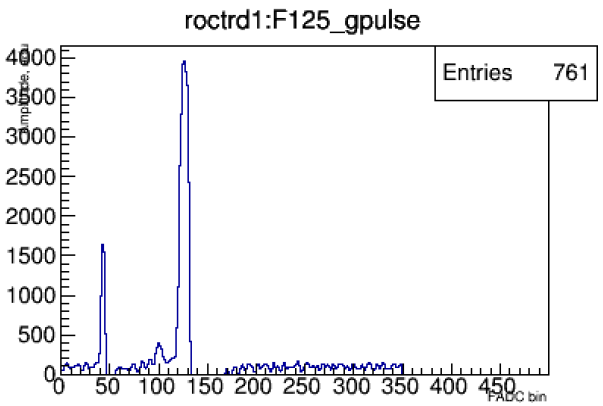
Hard TR-photons:

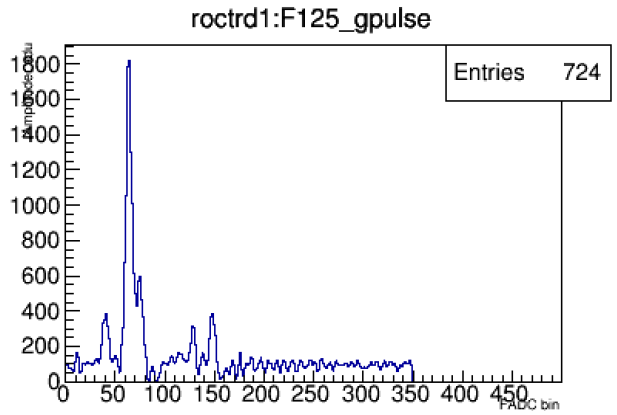
- Depending on energy of TR-photons, could escape detection (depends on detection length)
- Increase of radiator leads to increase of hard TR-spectra.

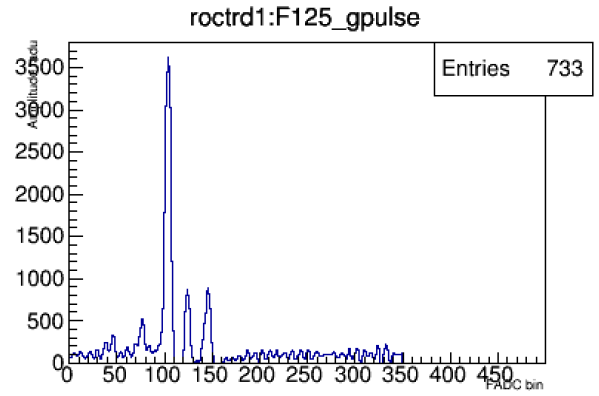
Separation/ Identification of TR-clusters and dE/dx clusters

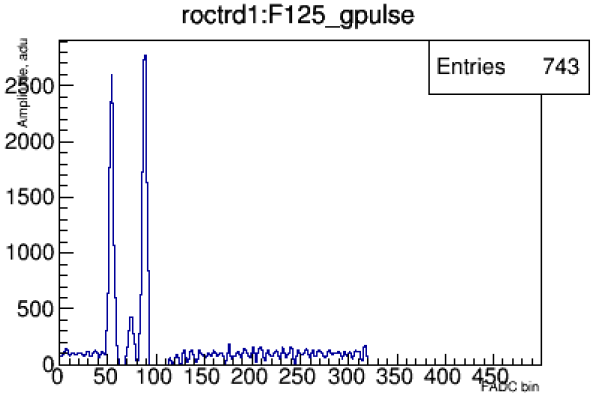
Signals from GEMTRD using FlashADC125

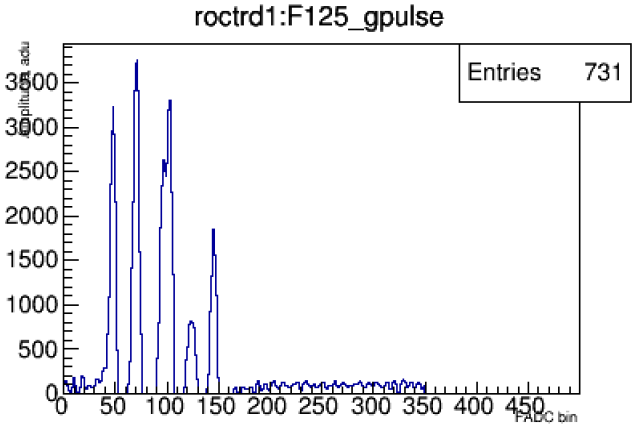


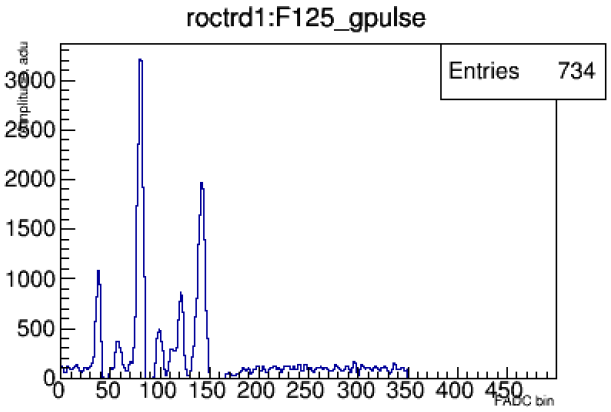


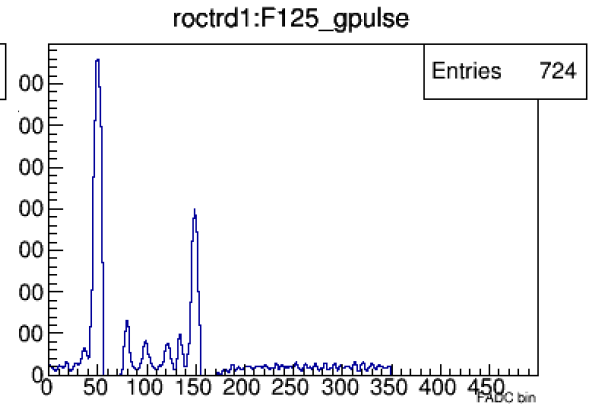


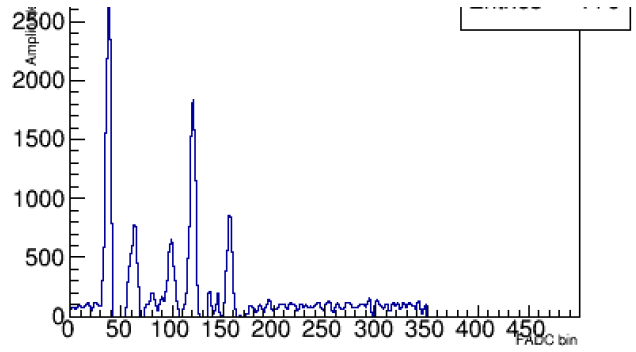










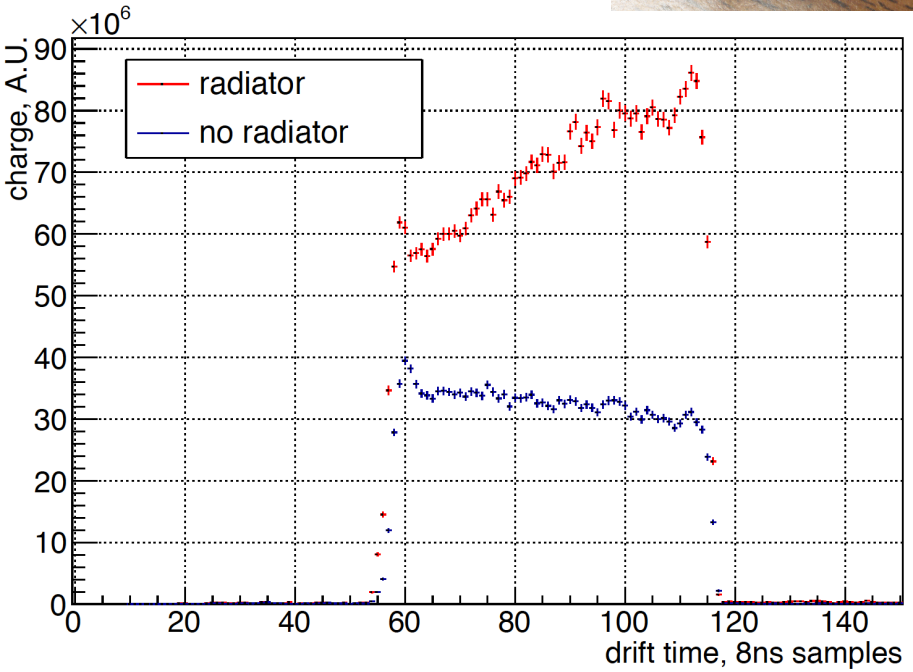


Charge as a function of drift distance

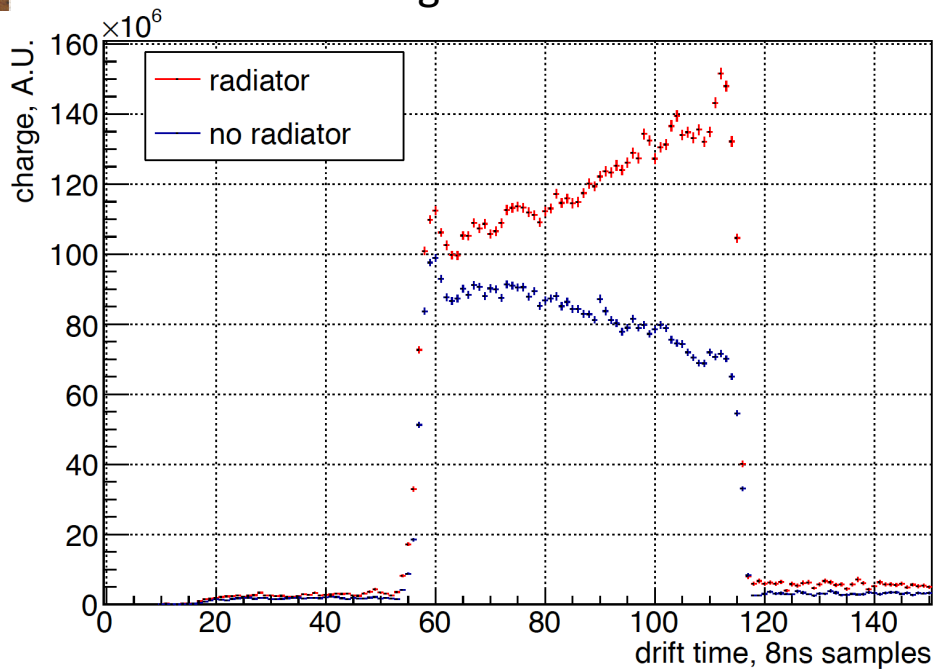
Fleece radiator:
Random oriented
Polypropylene fivers (20μm)

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

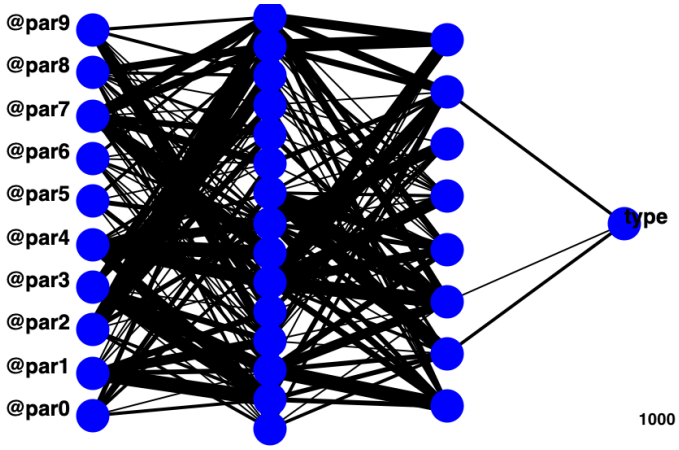
Fleece



Regular foils

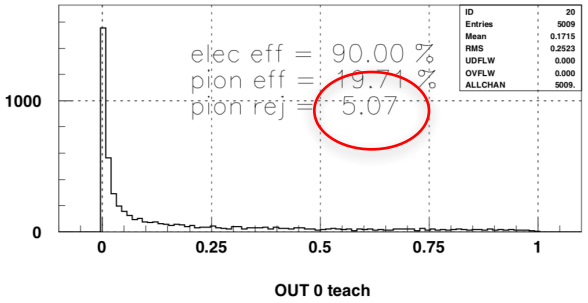


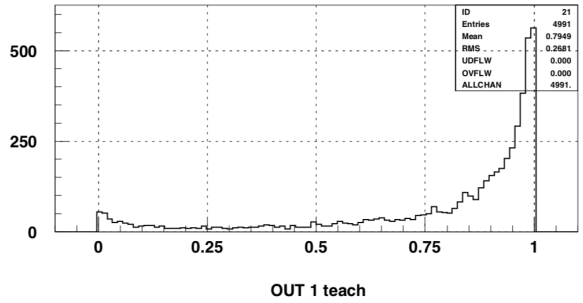
Machine learning technique

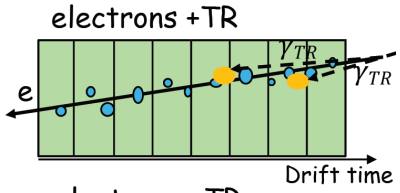


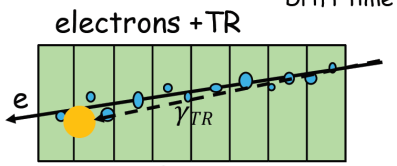
Used different methods/programs (JETNET, Root based-TMVA, etc) for cross-check.

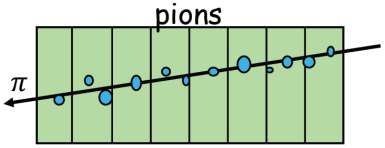
Neural network output for e/π identification



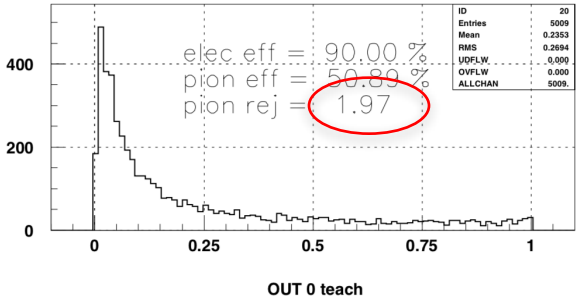


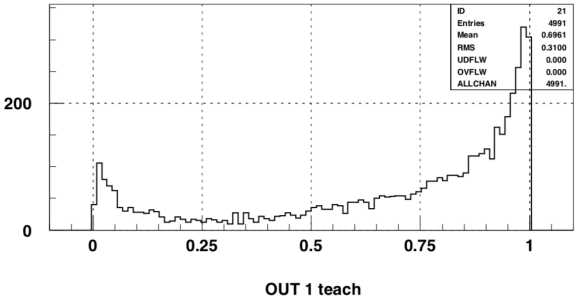






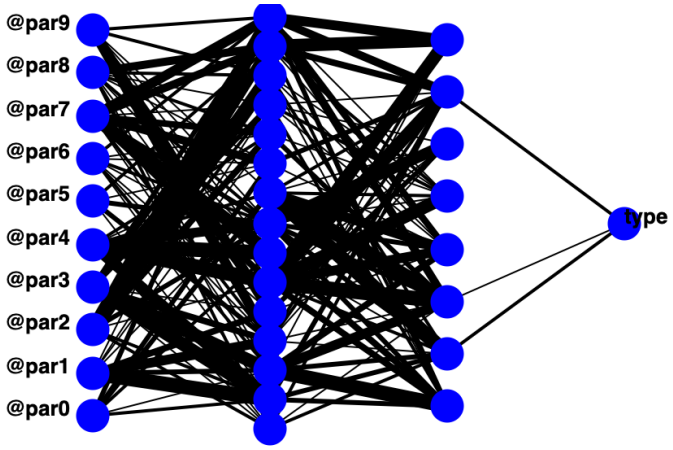
Neural network output for electrons with radiator and without radiator



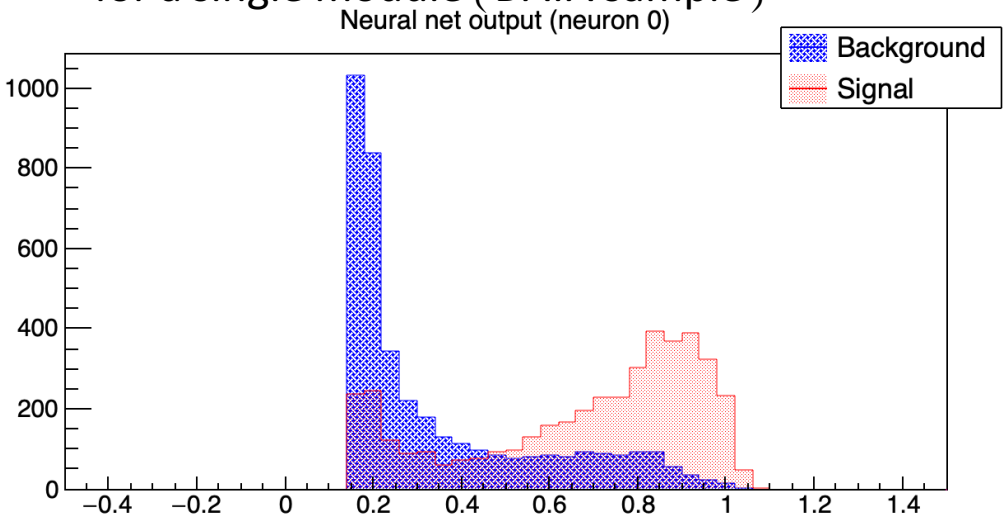


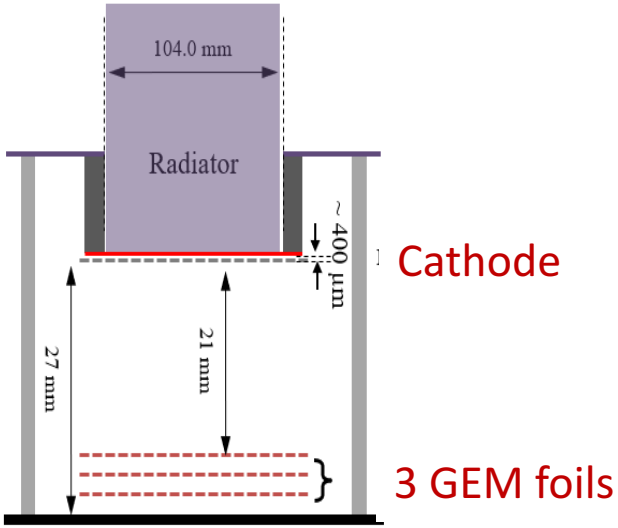
Monte Carlo Sample

Machine learning technique

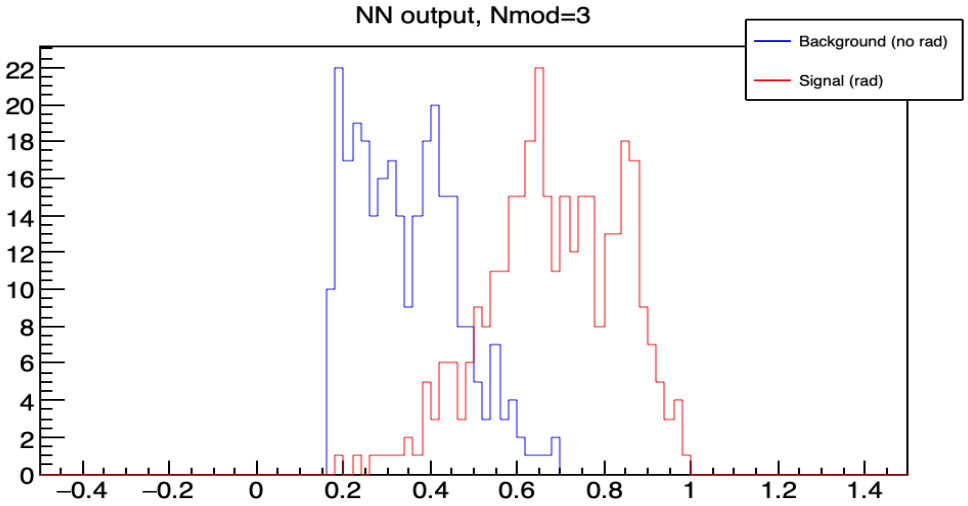


Multilayer perceptron output
for a single module (DATA sample)





propagation for 3 modules (bottom) for real data sample

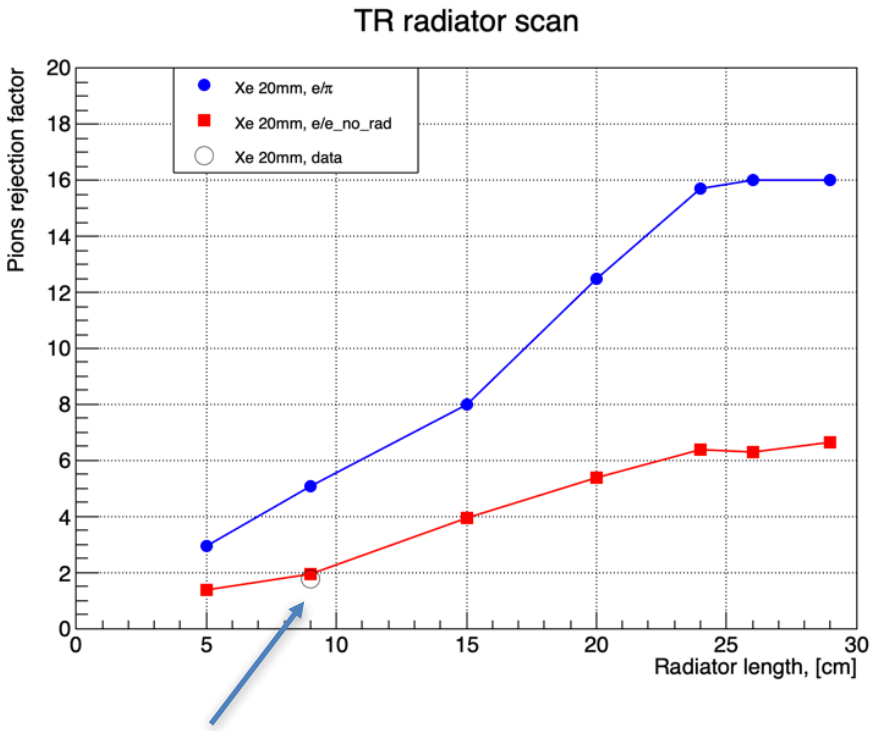


e/π rejectrion

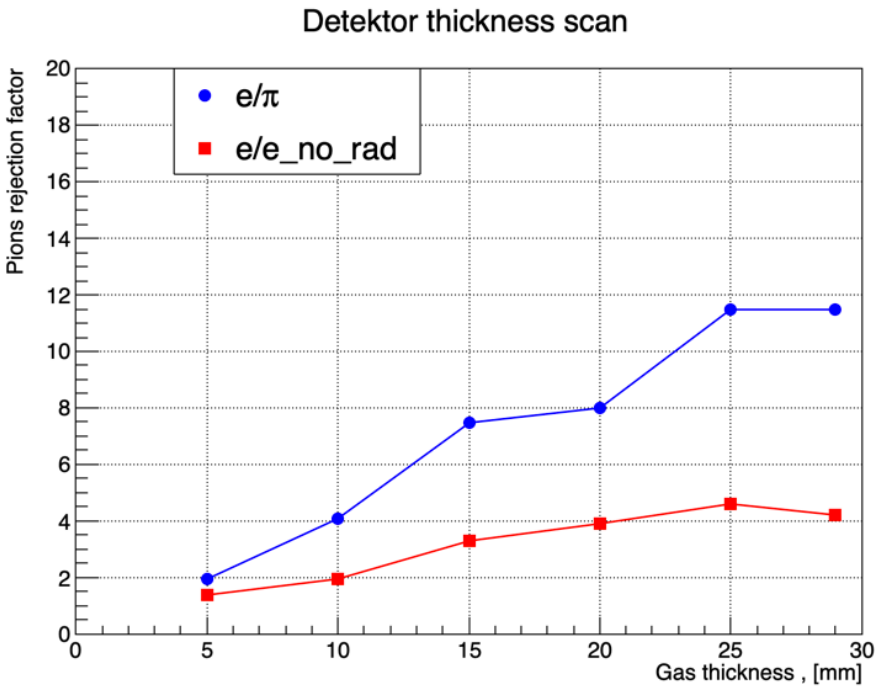
Detector	Dead material in front	Radiator	e/π	$e/e_{no\ radiator}$	$DATA_{e/e_{noR}}$
20 mm	no dead material	20 cm	14.4	6.3	
20 mm	400 μm Xe, Kapton 75μm	20 cm	12.5	5.38	
20 mm	as above	5 cm	2.94	1.37	
20 mm	as above	9 cm	5.07	1.97	1.8
20 mm	as above	15 cm	8.0	3.94	
20 mm	as above	26 cm	16.0	6.3	
20 mm	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

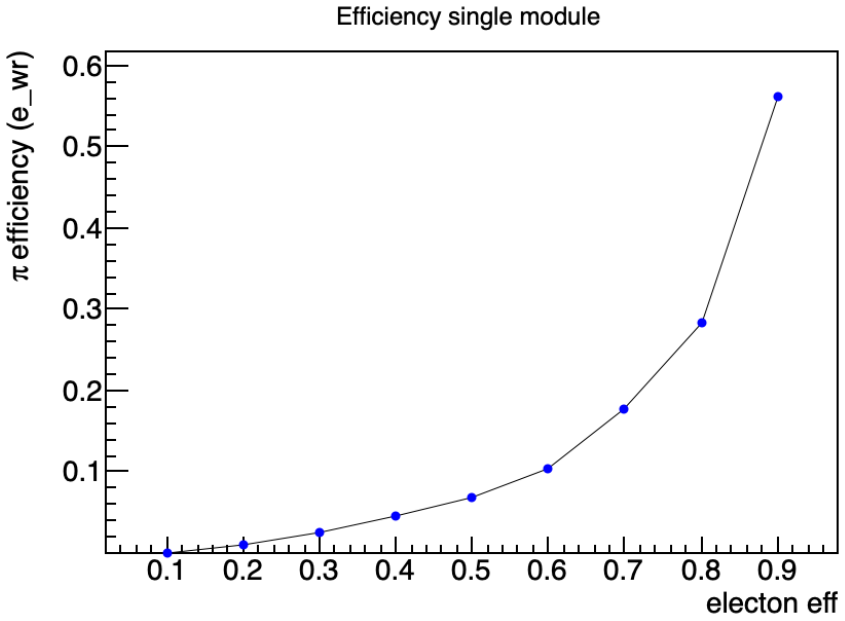
e/π rejection (MC and Data)

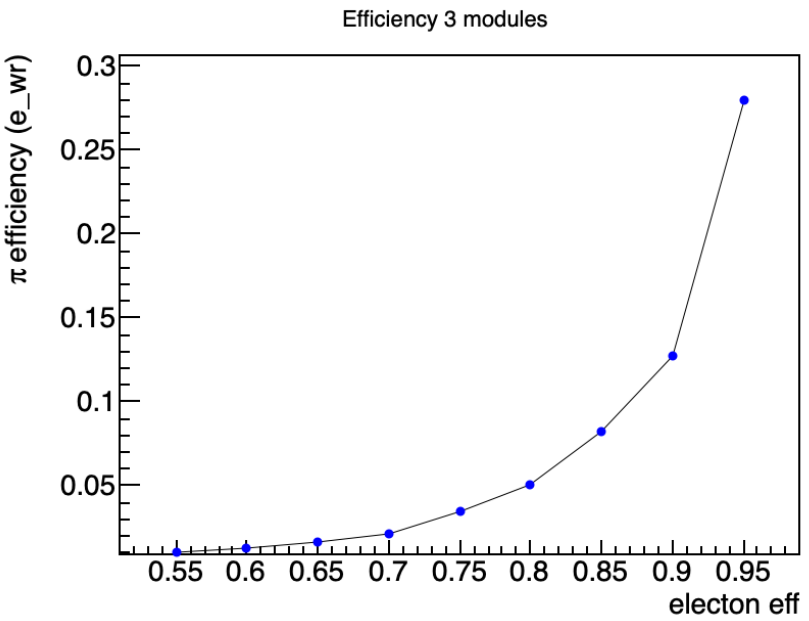


DATA point



e-efficiency vs rejection





For 3 modules with e-efficiency 80% e/e_noR rejection ~20.

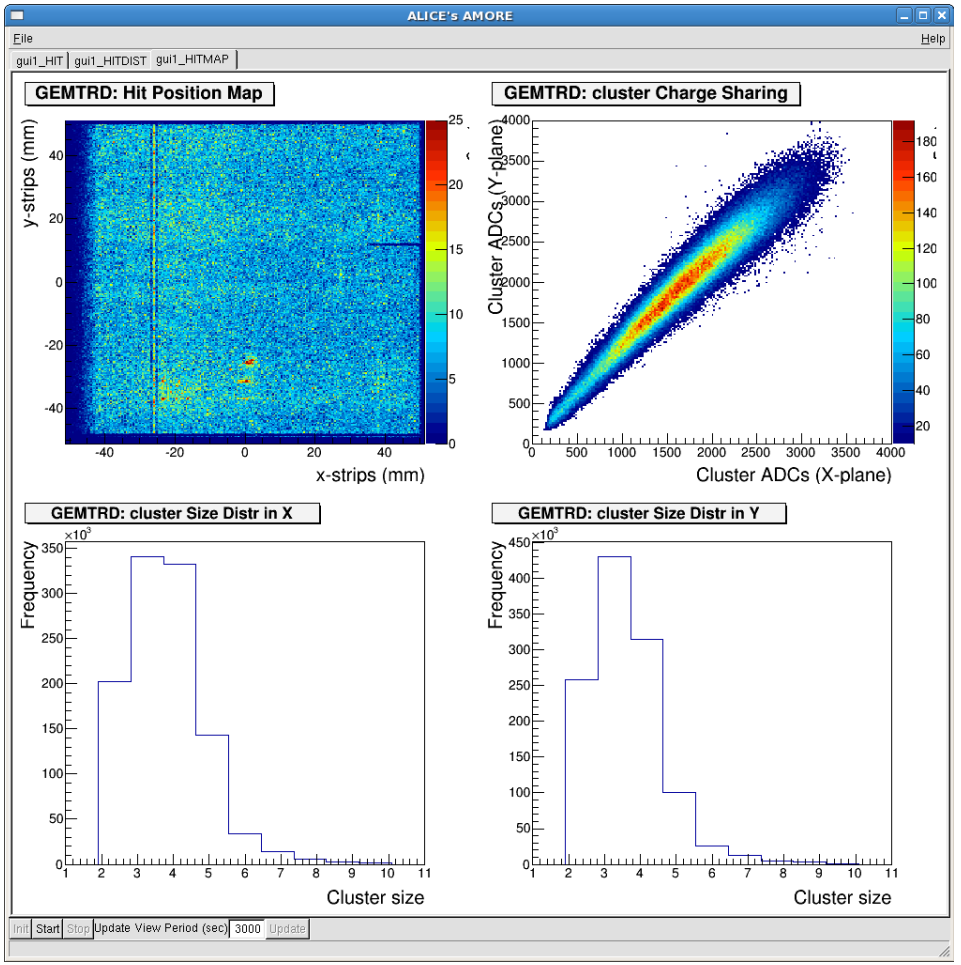
What we will do within next few months

- Test Module with different (%) gas mixtures: gas system is ready. Test gas-mixture for contaminations.
- Test Cr module: new prototype is ready and under a test at UVA
- Continue Monte Carlo simulation and data analysis
- Collaboration with tracking and streaming readout consortia
- Planning to present our results at conferences and prepare a publication

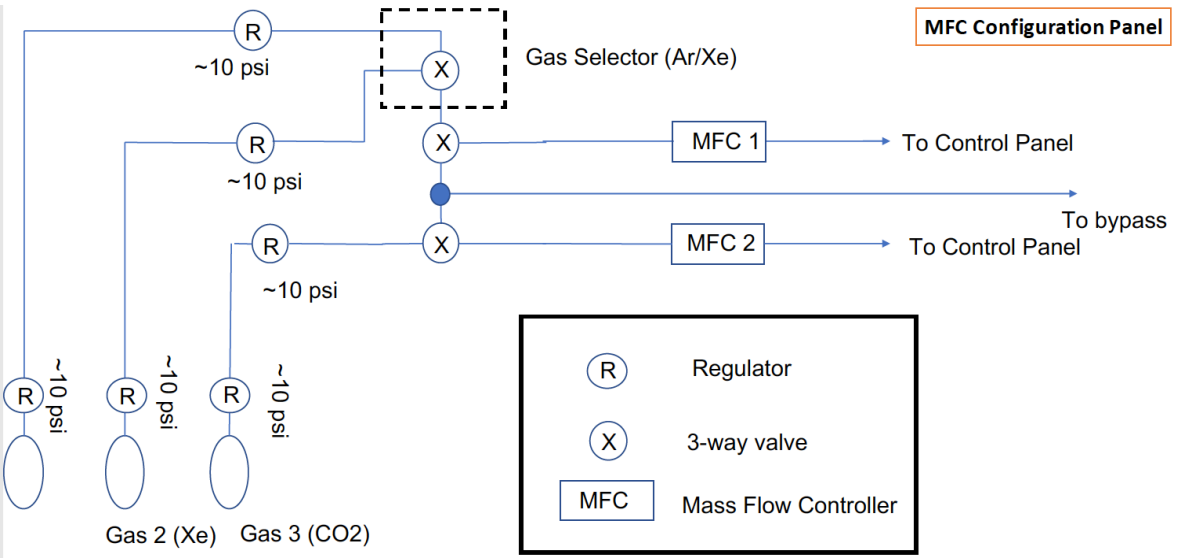
Test module

- test of Cr-GEMTRD prototype
- Testing GEMTRD tracking performance with 2 standard GEM track modules with the same setup at JLAB.
- Test of noise performance (noise reduction)

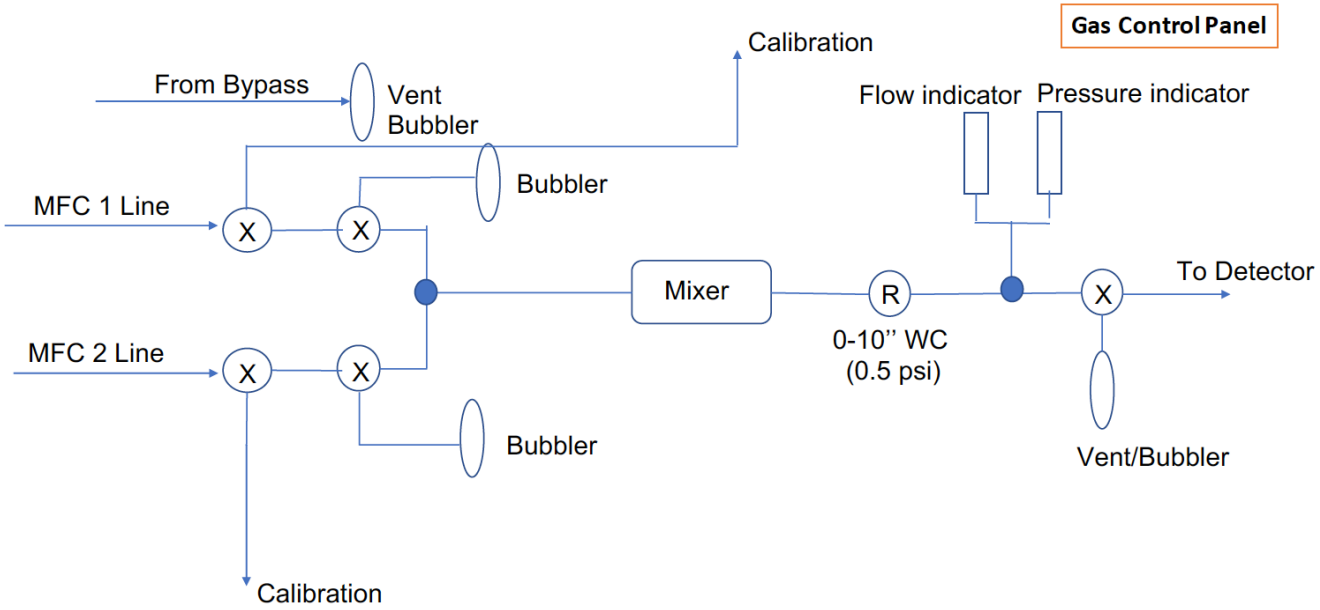
Performance of GEM-TRD module with Fe^{55} (Lab test at UVA)



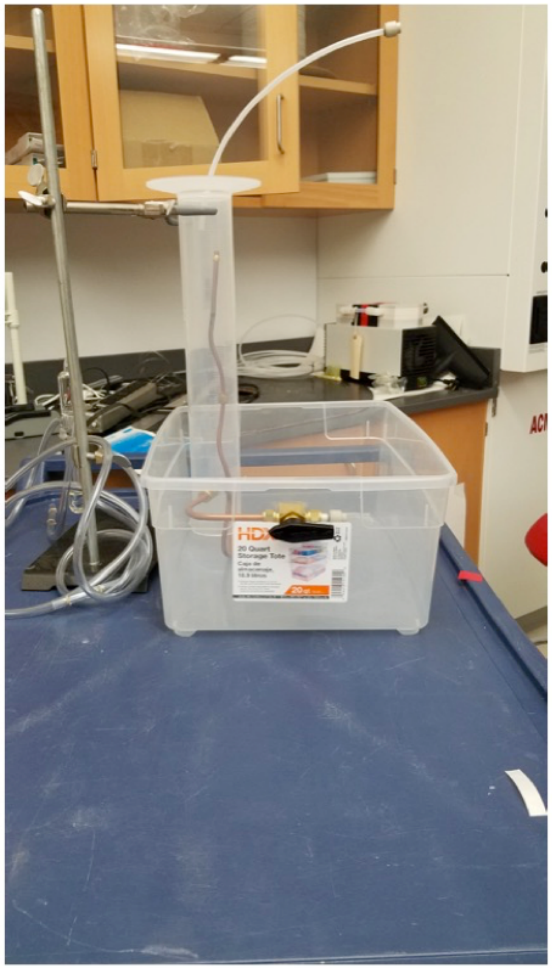
GAS system (Temple U.)

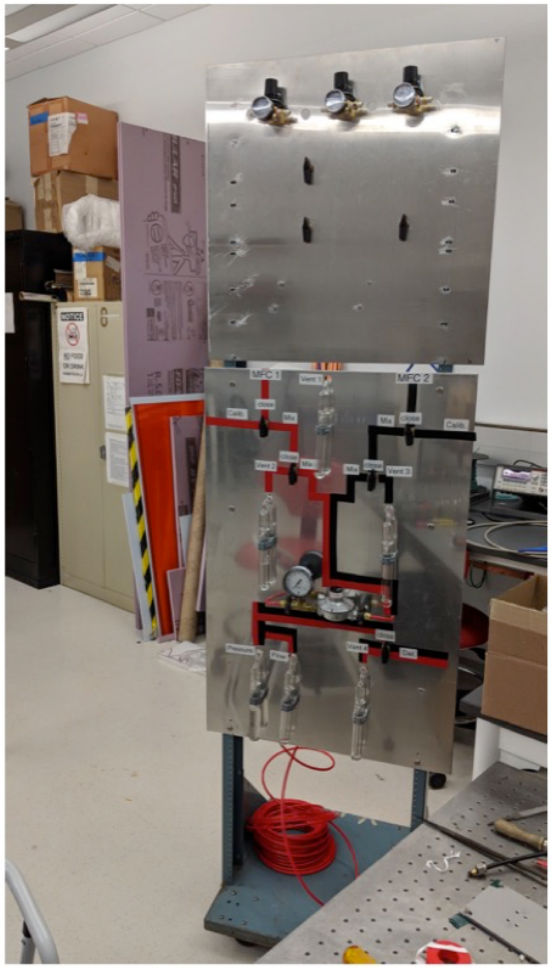


- Without a re-circulation and a purification system (too early stage of R&D)
- Mixing system to mix custom gas concentrations
- Flow controller, CO_2 controller



GAS system at Temple U.





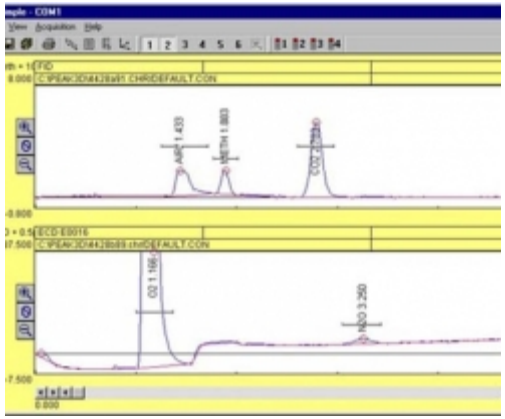
Installed at Hall-D, waiting for a final approval for operation under high-pressure.

Gas quality monitoring system

gas analyzer to begin quantifying and monitoring contaminations and to measure the concentrations of the Xe and CO_2 gasses.

-> split a cost with Hall-D : our contribution $7k (40%)

SRI 8610C



Electronics:

	MHz	ns/bin	Peaking time	Range	Channels/chip cost	ADC bits	Shaper
FlashADC125	125	8	30ns	$1\mu s$ or stream	$50/channel	14bit	-Undershooting -No baseline restorer
APV25	40	25	50ns	625ns	128 chan/chip		Analog output (no digitalization)
DREAM (CLAS12)	40	25	50ns		64chan/chip		Analog output (no digitalization)
VMM3 (ATLAS)	4	250	25-200ns		64chan/chip	10bit	L0 or continuous
SAMPA (ALICE)	10-20	100-50	160ns	Stream 3.2Gbit/s	32chan/chip 30$/chip 1$/channel	10bit	500ns- return to baseline Baseline restorer, DSP (zero-suppression, thr)

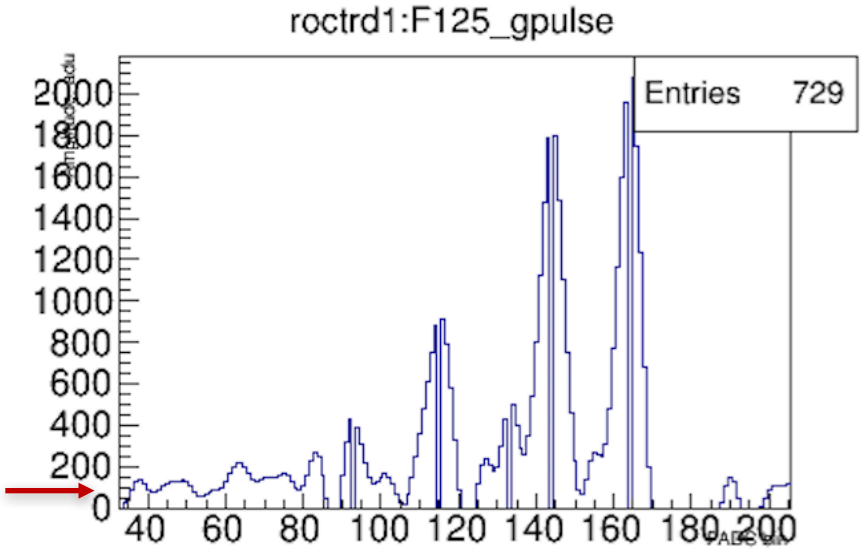
Summary

- 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 has been performed
- First test beam measurement has been performed, new test is on going
- Looking forward to a collaboration with tracking and readout consortiums!

Thank you!

Backup

Readout hardware: find a cheaper solution/replacement of FlashADC125 (<<$50/channel): FADC125 have a timing resolution of 8ns/bin, and covers a whole drift time range >1μs .



FADC 125MHz == 8ns/bin
Preamp peaking time: 3-4 bins ~ 20-30ns
need better
Problems: undershooting (base at 100ADU),
loosing signal =>
need better shaper and
need also baseline restorer
Need: dE/dx, Cluster counting + timing
Coverage ~ 1μs

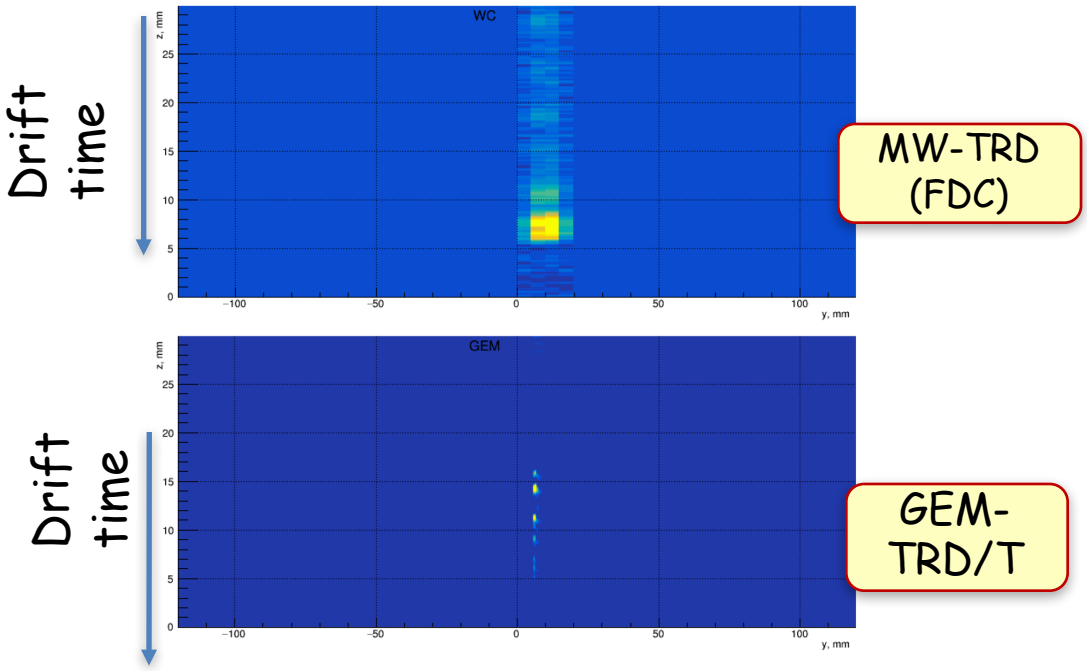
Available electronics for GEM

-APV25: too few bins, coverage x
-VMM3 : 200ns/bin x
-SAMPA: 10-20 MHz only x but…

lots of good features inside SAMPA:
- 32channels/chip 30$/chip => 1$/channel v
- Shaper/preamps v
- Baseline restorer v
(similar to ASDBLR/ATLAS)
- DSP: Zero suppression, thresholds v
- ASICs : could implement later any PID algorithms v

In addition (plans for FY19)

5. Tracking: evaluate the performance of our prototype as a tracker (space point resolution, Xe vs Ar etc) (no cost)



6. Radiator optimization: we need to identify and test promising new radiator materials to optimize the yield of TR-photons (no cost)

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