New proposal:

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:

- TRD experts:
  - ✓ Yulia Furletova (EIC, Jefferson Lab)
  - ✓ Sergey Furletov (Hall-D, Jefferson Lab)
  - ✓ Lubomir Pentchev (Hall-D, Jefferson Lab)
- GEM experts:
  - ✓ Kondo Gnanvo (University of Virginia)
  - ✓ Nilanga K. Liyanage (University of Virginia)
  - ✓ Matt Posik (Temple University)
  - ✓ Bernd Surrow (Temple University)

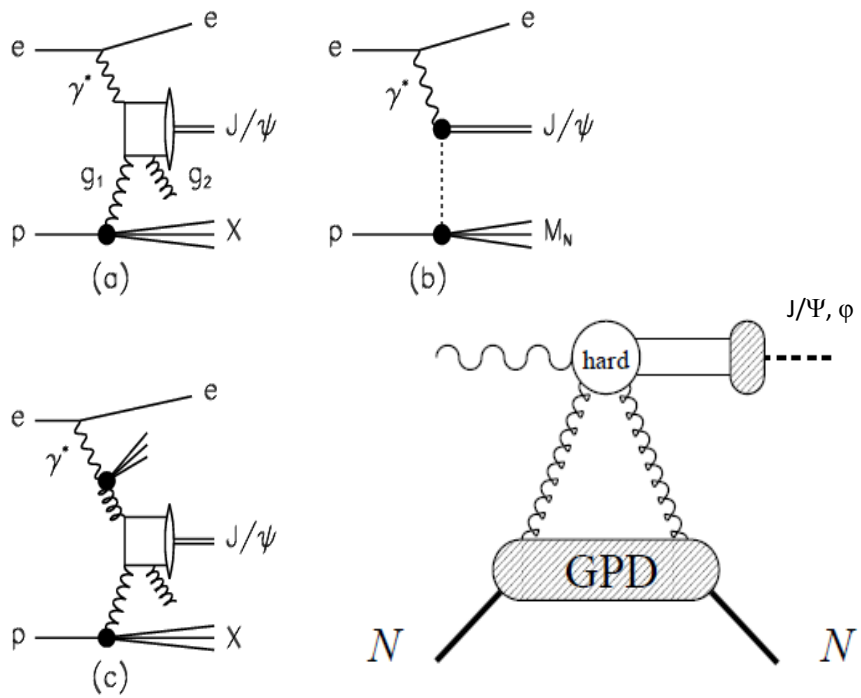
OUTLINE:

- Motivation. Electron identification for EIC
- Detector concept
- Very first test beam results
- R&D program
- Budget

Electron identification at EIC: J/ψ

Spatial gluon distribution from J/Psi photoproduction and DVCS

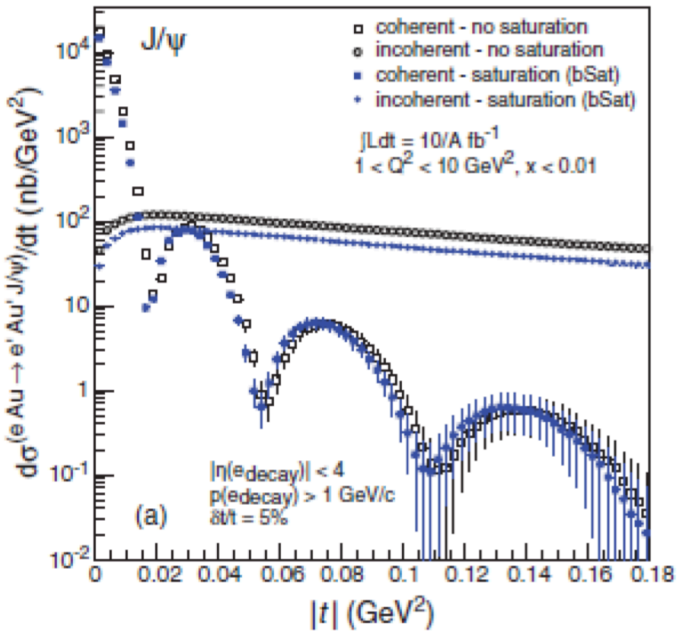
ZEUS: hep-ex/9708010



Br ($J/\psi \to e^+e^-$) ~6%

Br ($J/\psi \to \mu^+\mu^-$) ~6%

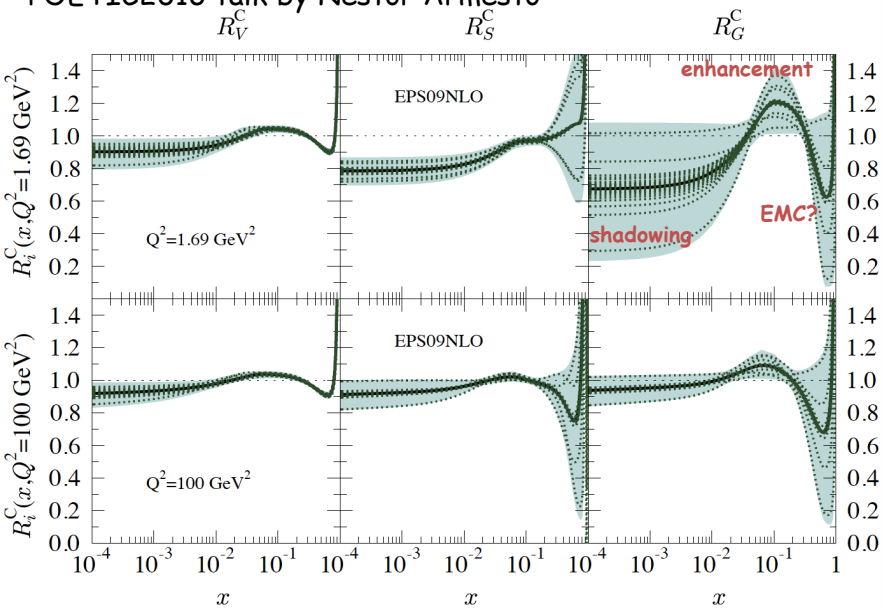
Saturation
Coherent Exclusive Diffraction

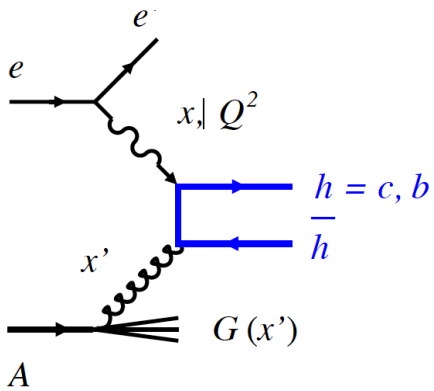


Electron Identification at EIC: Beauty

Open beauty as a direct gluon probe

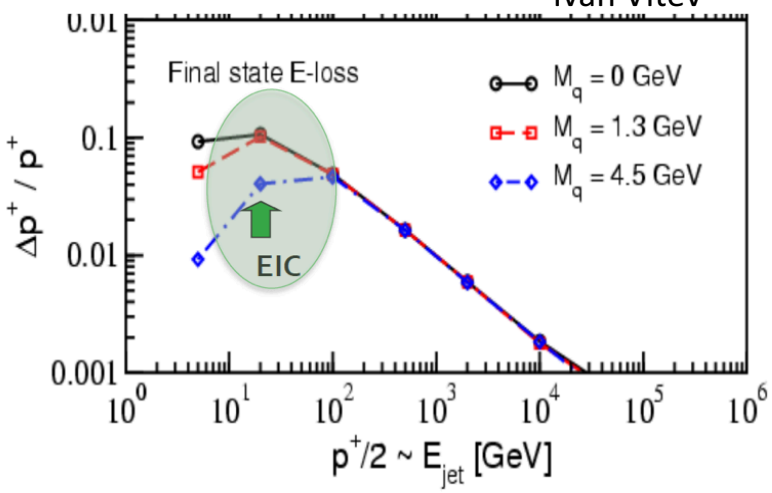
POETIC2016 talk by Nestor Armesto

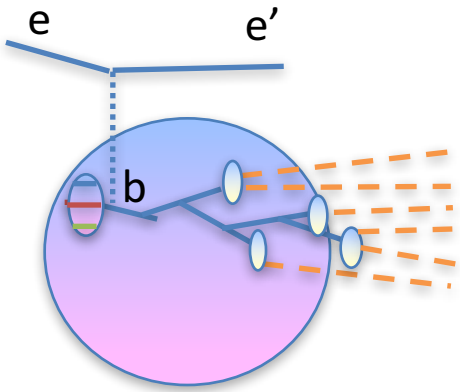




In-medium propagation and hadronization of heavy quarks

Ivan Vitev



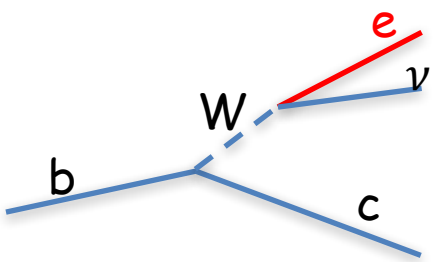


Electron Identification at EIC:

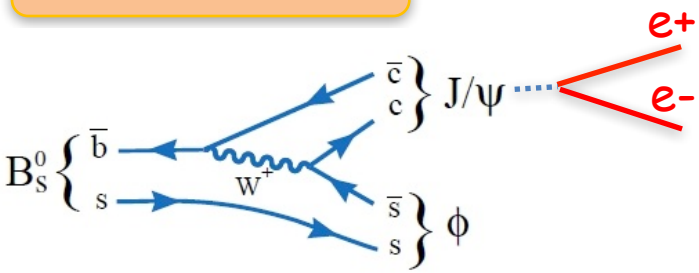
Beauty and Charm:

b -> e (at HERA σ ~ 72 pb)
DESY-11-005

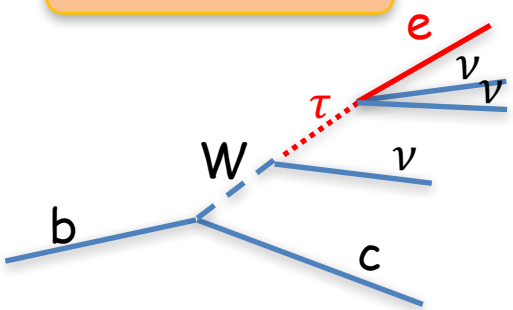
b -> c + e



b -> J/Ψ -> e+e-



b -> τ -> e



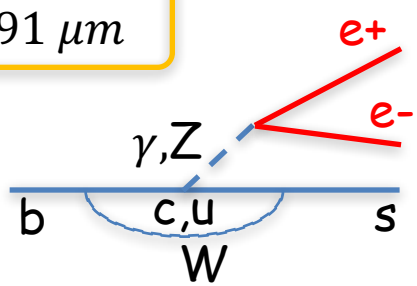
Br ($B^{\pm}$->e+ν+X_C) ~10%

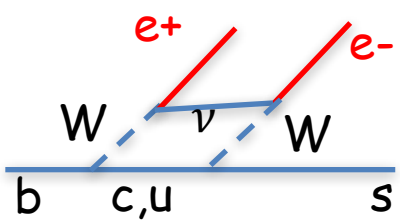
Br (b -> J/psi X) ~ 1.16%

Exclusive:
BR($B^{\pm}$->J/psi (e+e-)+ K^+) ~ 10^{-3}

$c\tau$ $(B0)$ ~457 μm,
$c\tau(B\pm)$~ 491 μm

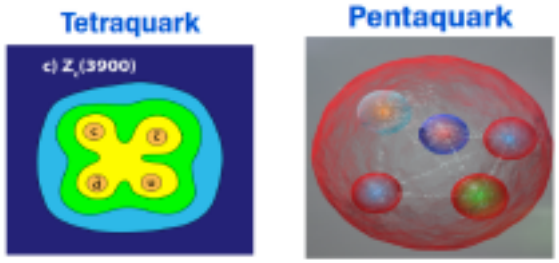
Br (D+ -> e + X) ~16%
Br (D0 -> e + X) ~ 6.5%

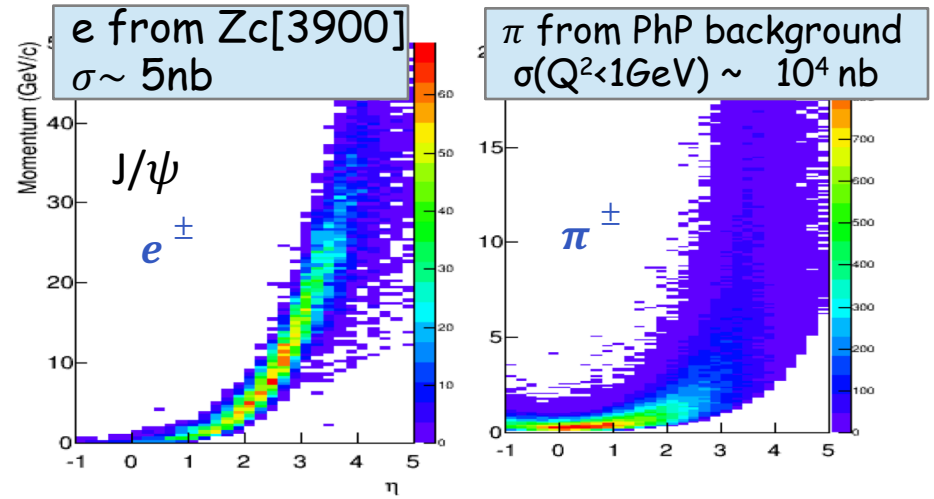




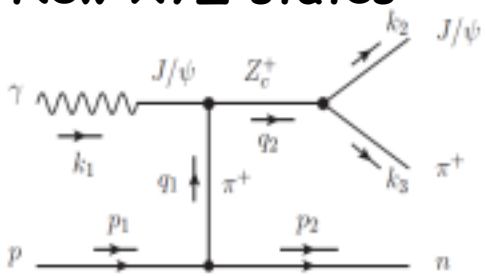
New XYZ states at EIC

Secondary e± are boosted into initial proton beam direction



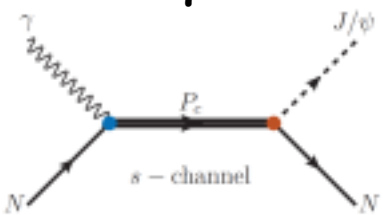


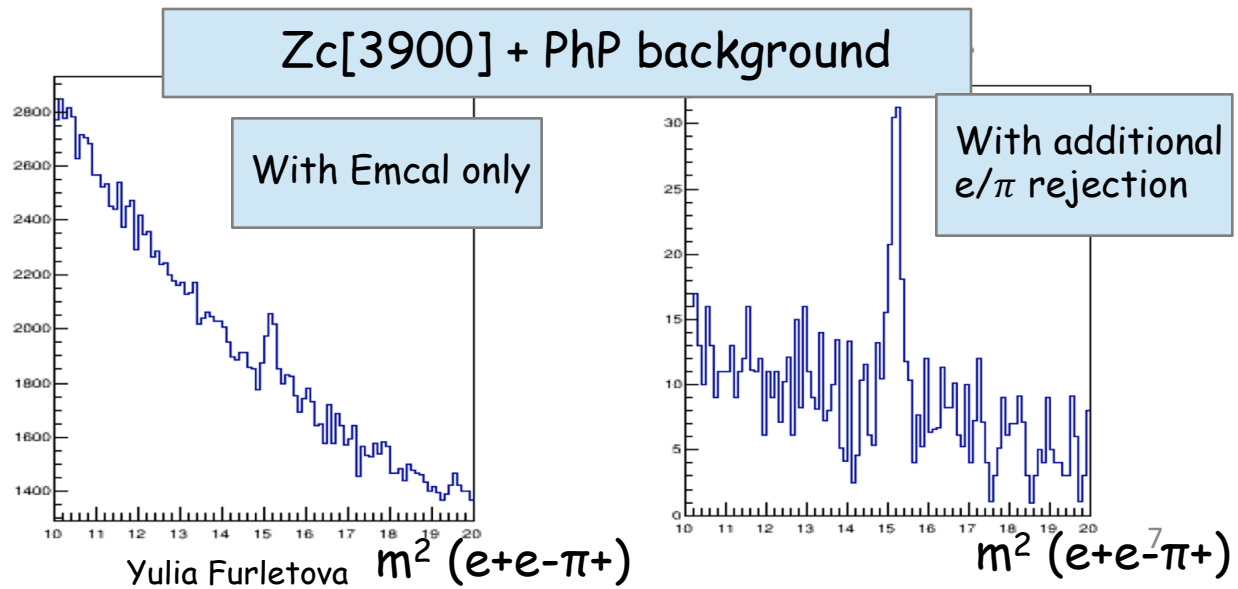
New XYZ states



Ca. 1 out of 100 π will produce signal in EMCAL similar to electrons

Pentaquarks





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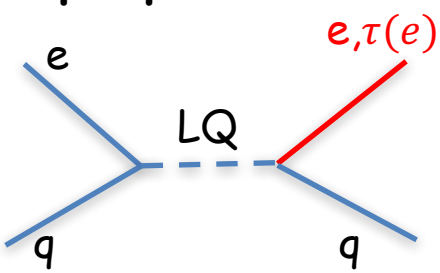
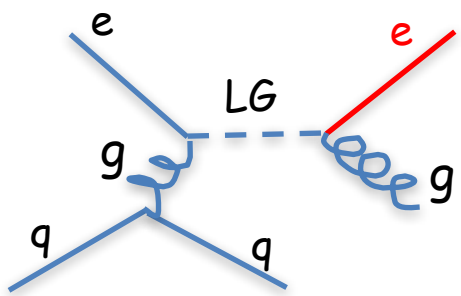
Electron Identification for Beyond the Standard Model Physics

Leptoquarks



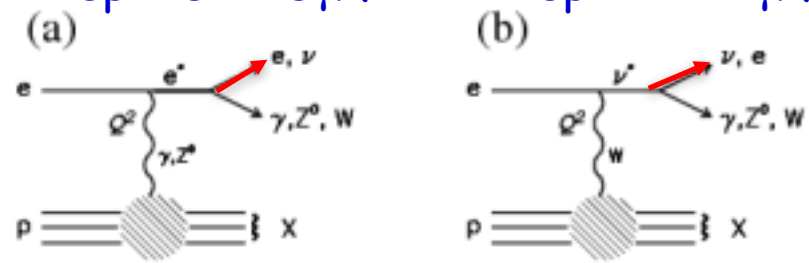
Leptogluons



Excited Fermions

ep-> e*-> eγX

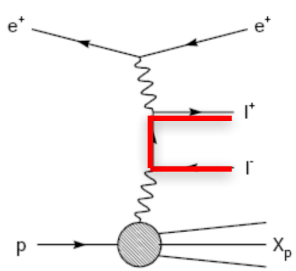
ep-> ν*->νγX



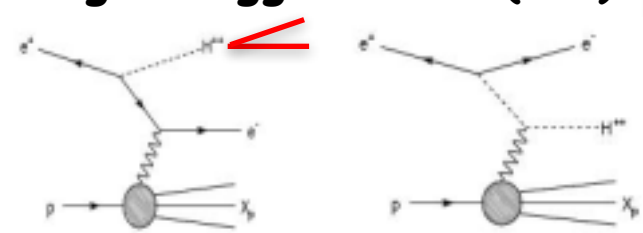
Test of the Standard Model

Comparison of the yield ee, eee, eμ, μμ, eμμ, etc.

Di-leptons:



Resonance production, e.g. Doubly-charged Higgs bosons ($H^{\pm\pm}$)

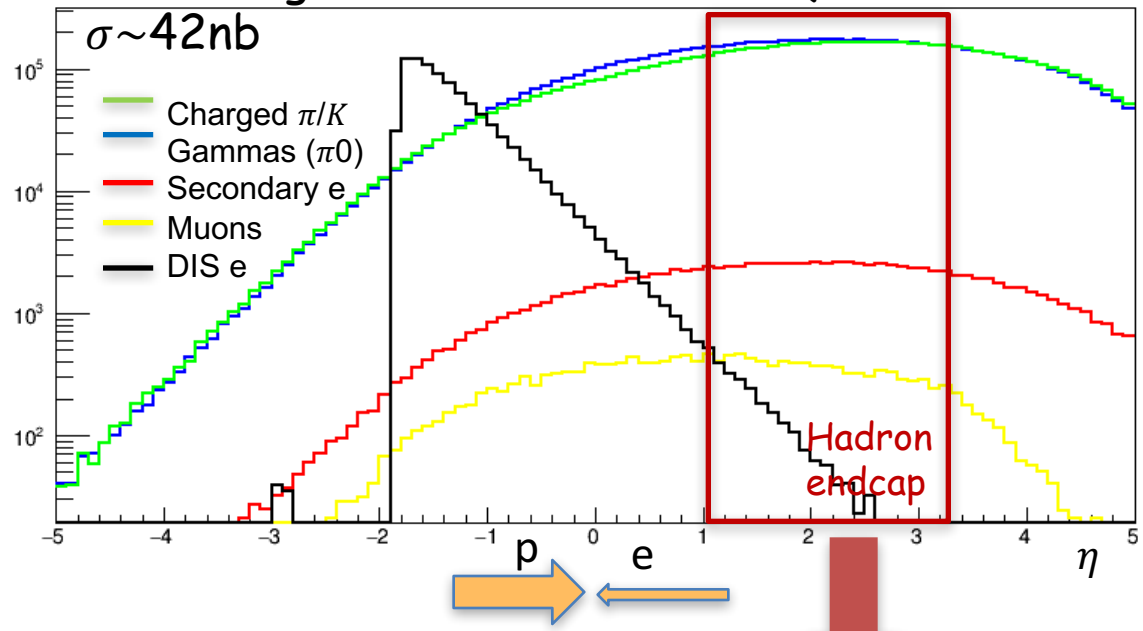


$H^{\pm\pm}$ decays into ee, eμ and eτ pairs

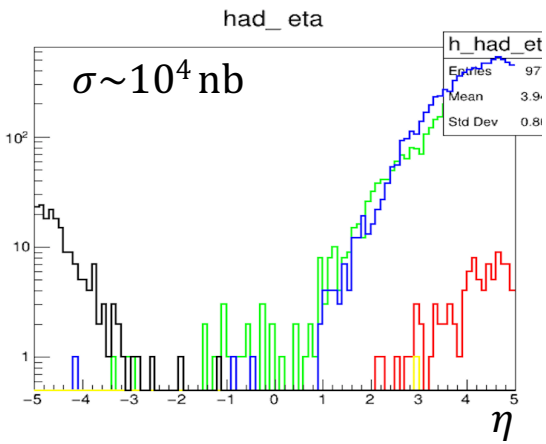
Event kinematic at EIC:

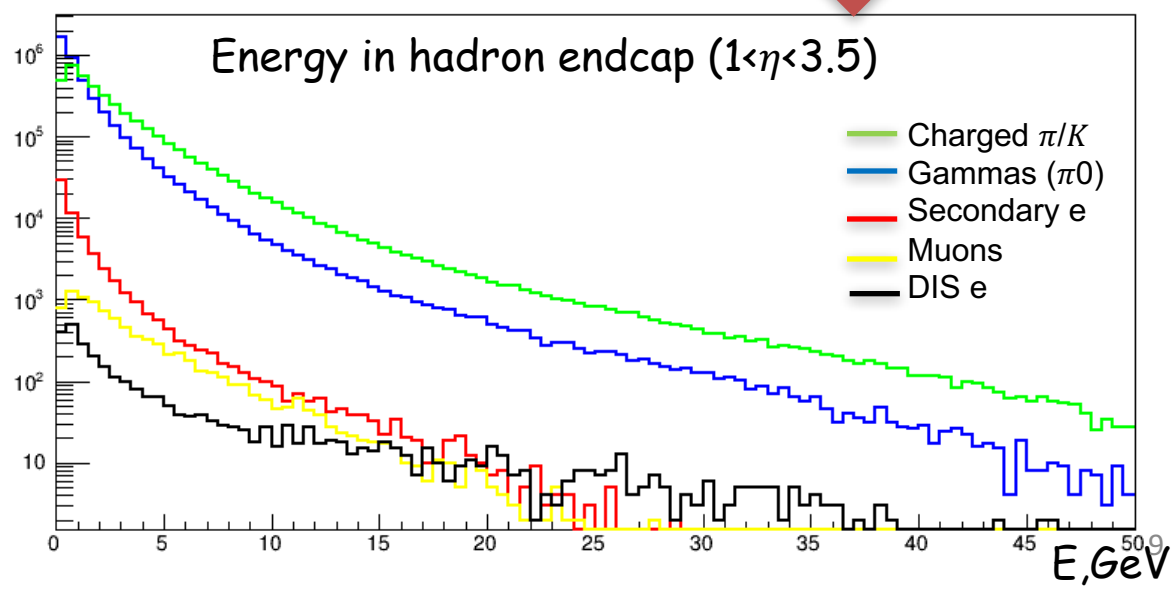
- Charged hadrons (EM calorimeter e/π ~ 1:100)
- $\pi 0$ -> $\gamma\ \gamma$ (in EMCAL signal equal to e)
- γ-> e+e-

Angular distribution for Q^2>10GeV^2



Angular distribution for PhP





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Hadron endcap

Environment:

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

Needs:

- 10^3-10^4 e/π rejection factor required over wide (1-100GeV) energy range in the forward region (EMCAL e/π rejection 50-100)
- High granularity tracker with low material budget, not very expensive=> GEM

Proposal:

- Tracker combined with TRD/PID function: which could provide additional e/hadron rejection 10-100 and will cover energy range 1-100 GeV =>

GEM based transition radiation detector/tracker

GEM-TRD/T

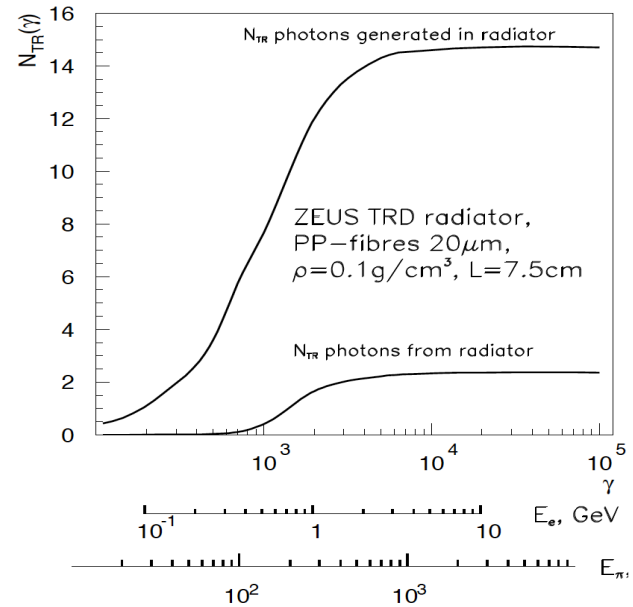
Yulia Furletova

Why transition radiation detector?

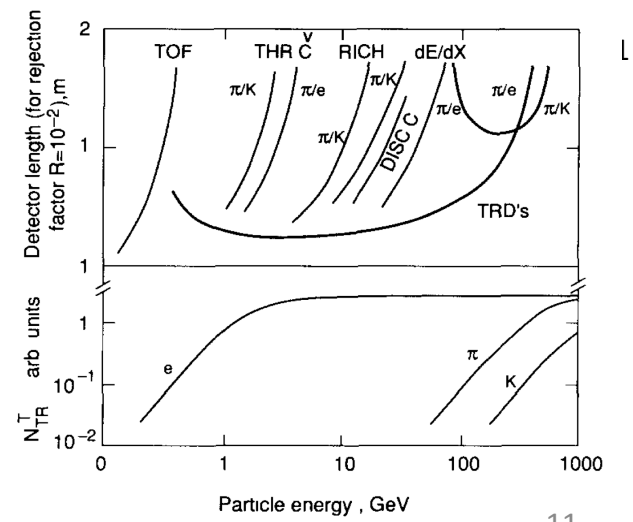
- TRD separate particles by their gamma factor
- e/π separation in high $\gamma = E/m$ region (1-100 GeV) where all other methods are not working anymore.
- Provide high rejection factor for a small detector length in a wide range of a particle momentum.
- Identification of the charged particle "on the 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).

J.Tandler



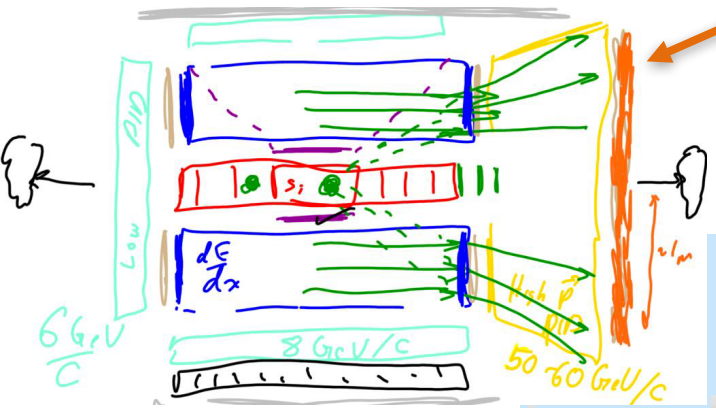
Length of detector for rejection factor 100.



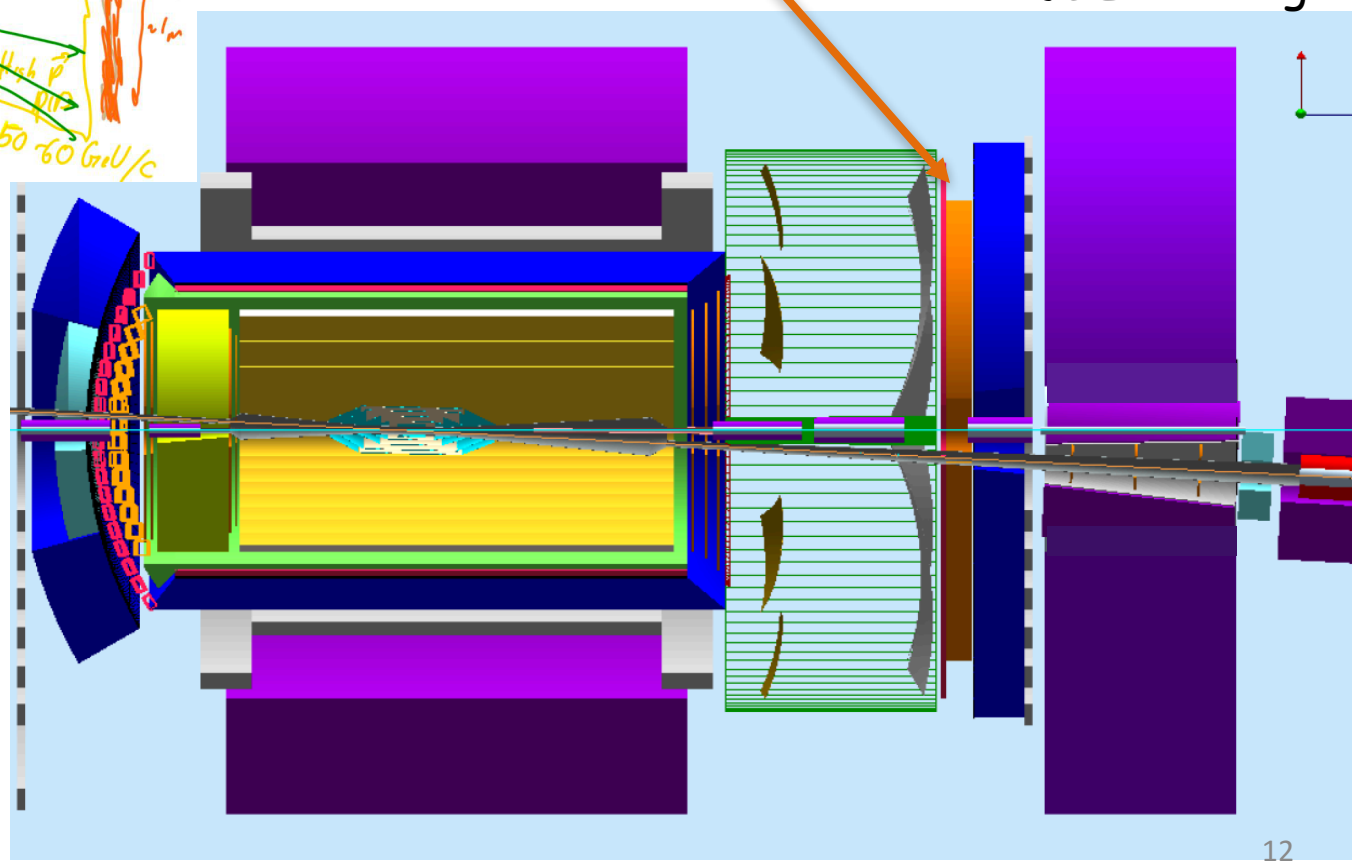
Hadron endcap

R&D tracking consortium

GEM-TRD/T

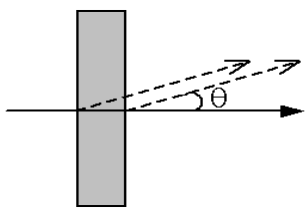


JLEIC design



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



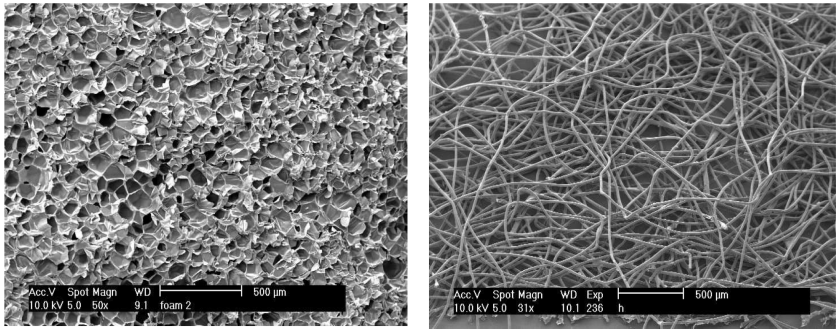
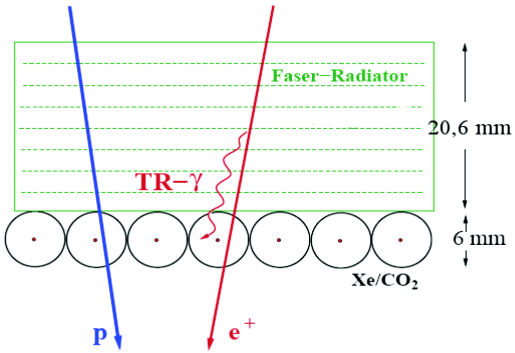
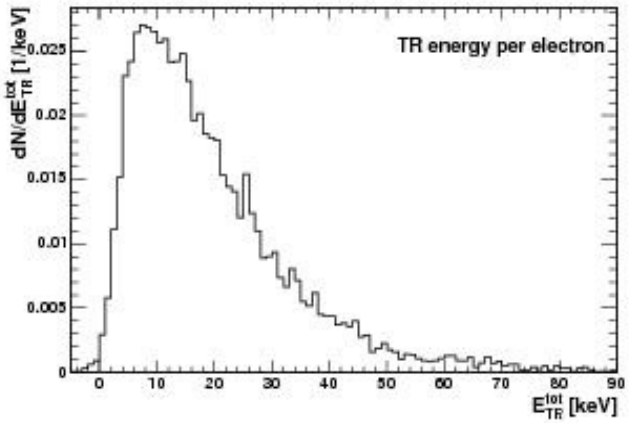


Figure 2: Electron microscope images of a polymethacrylimide foam (Rohacell HF71)(left) and a typical polypropylene fiber radiator (average diameter ≈ 25 μm) (right) [52].



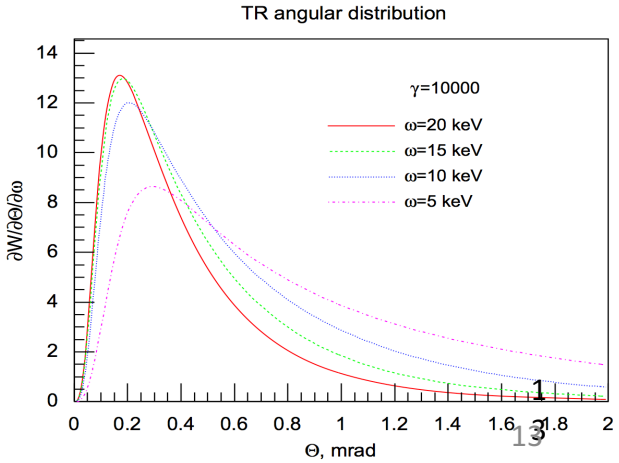


- the probability to emit one TR photon per boundary is of order α~1/137. Therefore multilayer dielectric radiators are used to increase the transition radiation yield, typically few hundreds of mylar foils.

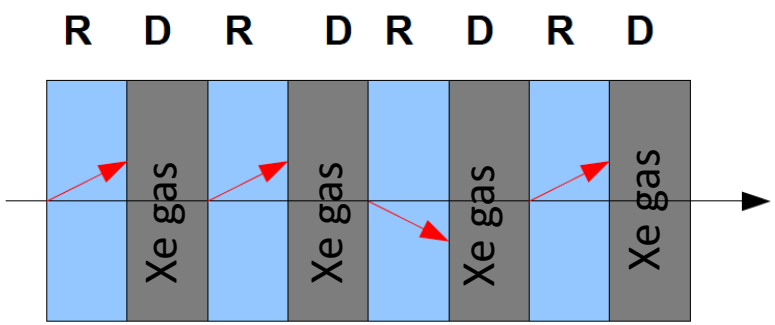
- TR in X-ray region is extremely forward peaked within an angle of 1/γ

- Energy of TR photons are in X-ray region (2 - 40 keV)

- Total TR Energy ETR is proportional to the γ factor of the charged particle

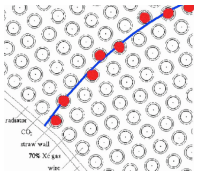


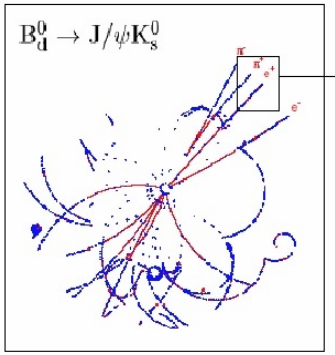
How easy to detect Transition Radiation ?

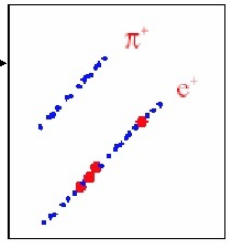


- Stack of radiators and detectors (sandwich)
- For "classical" TRD (straws, MWPC) gas with high Z is required for better absorption of TR photons: Xenon gas (Z=54)
- TRDs are not "hadron-blind" ! they see all charged particles dE/dx
- Several methods exist to identify TR photons on the top of dE/dx: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

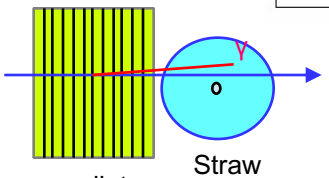
ATLAS TRT

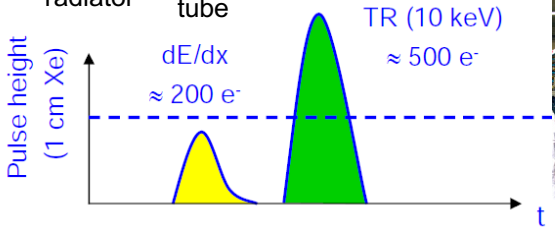


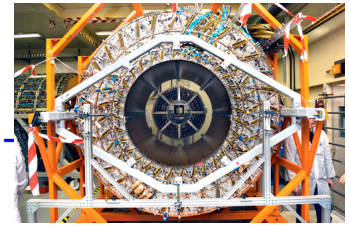




Simulated event, illustration of clusters from eletron/positron and pion hits – small blue dots are ionizing hits, large red dots are TR hits



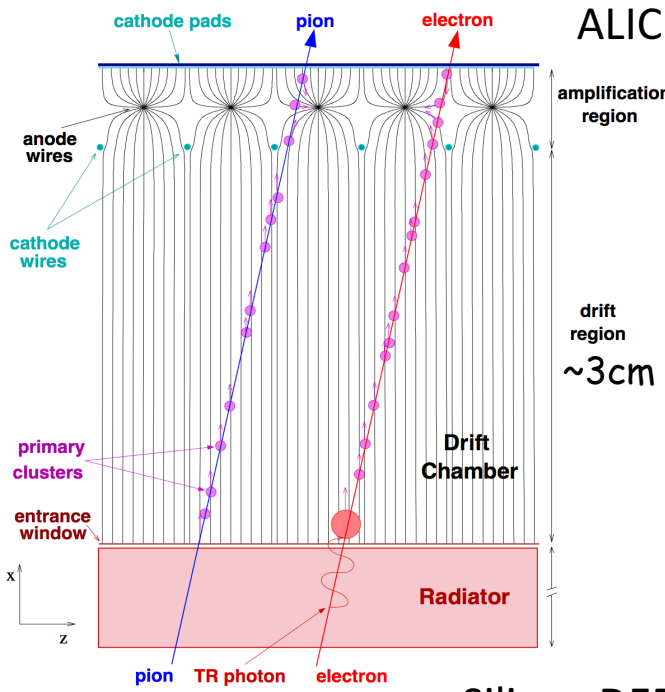




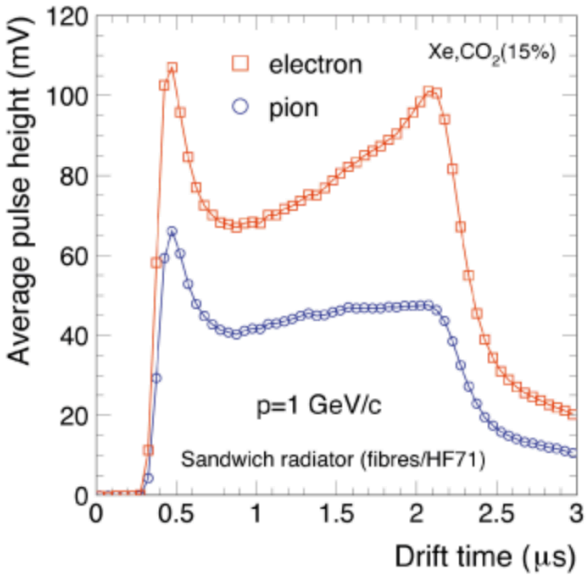
- **Discrimination by threshold** (ATLAS)
- **Average pulse height along adjacent pads (or along a track)** (ALICE) => (next slide)

TR detection in MWPC, Silicon

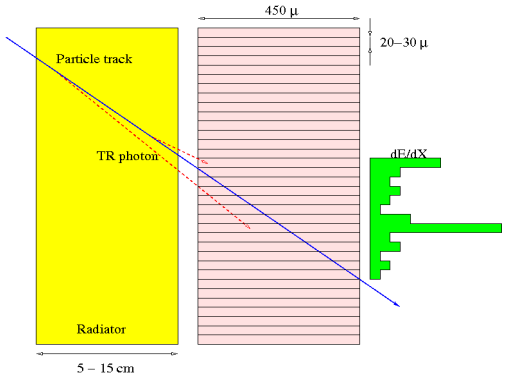
- With a MWPC:
For electrons - significant increase in the average pulse height at later drift times, due to the absorption of the transition radiation near the entrance of the drift chamber.



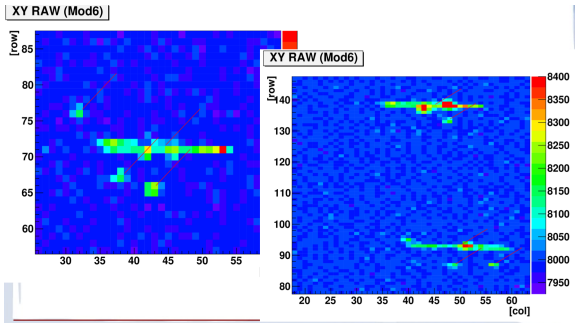
ALICE MWPC - TRD



- Similar effect with a silicon (DEPFET pixel), where TR clusters could be seen also as separate clusters



Silicon DEPFET-pixels TRD



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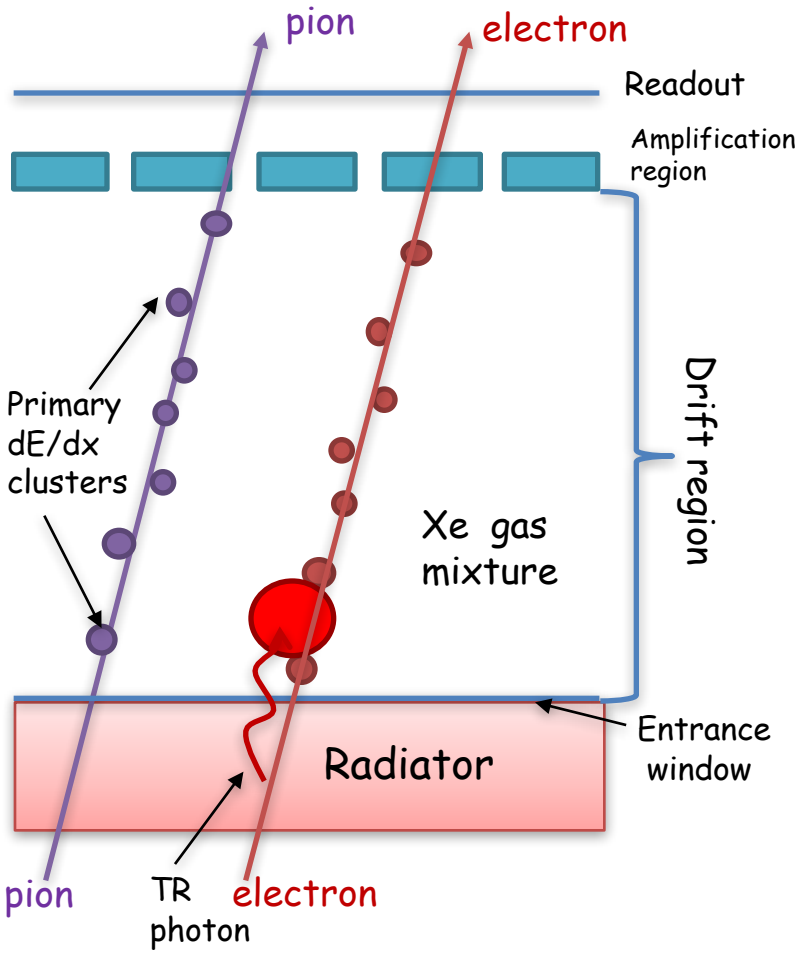
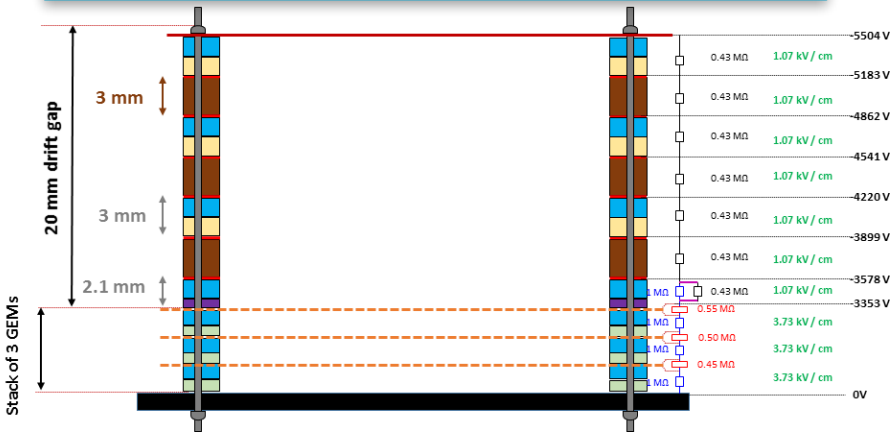
GEM as Transition Radiation detector and tracker for EIC

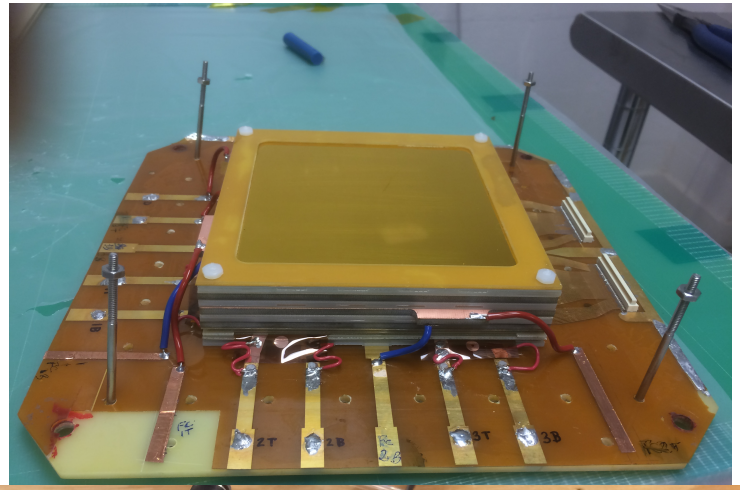
- High resolution tracker.
- Low material budget detector
- How to convert GEM tracker to TRD:
  - ✓ Change gas mixture from Argon to Xenon (TRD uses a heavy gas for efficient absorption of X-rays)
  - ✓ Increase drift region up to 2-3 cm (for the same reason).
  - ✓ Add a radiator in the front of each 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.



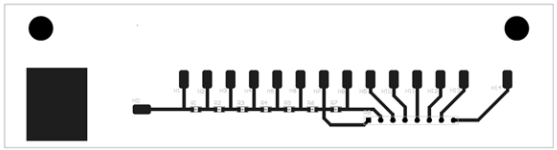
GEM -TRD/T prototype-0 @ UVA

GEM-TRD/T cross section, 20mm drift volume

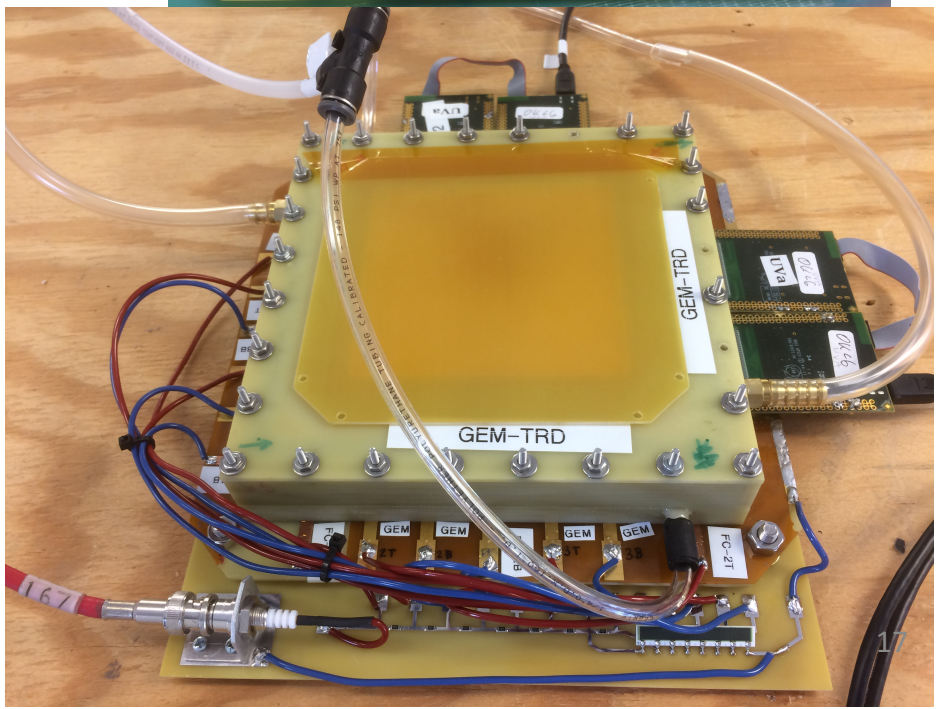




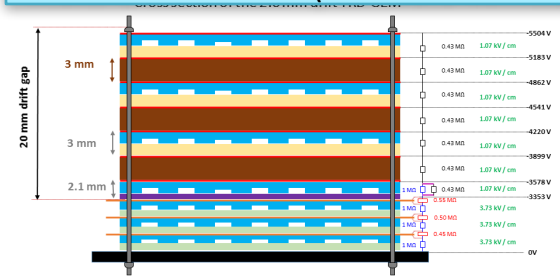
Drawing for the resistive divider



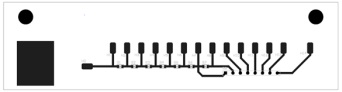
HV 5504 V,
Resistive Divider = 7.404 MΩ,
Max current = 747.3 μA



Walls cross section(for field correction)

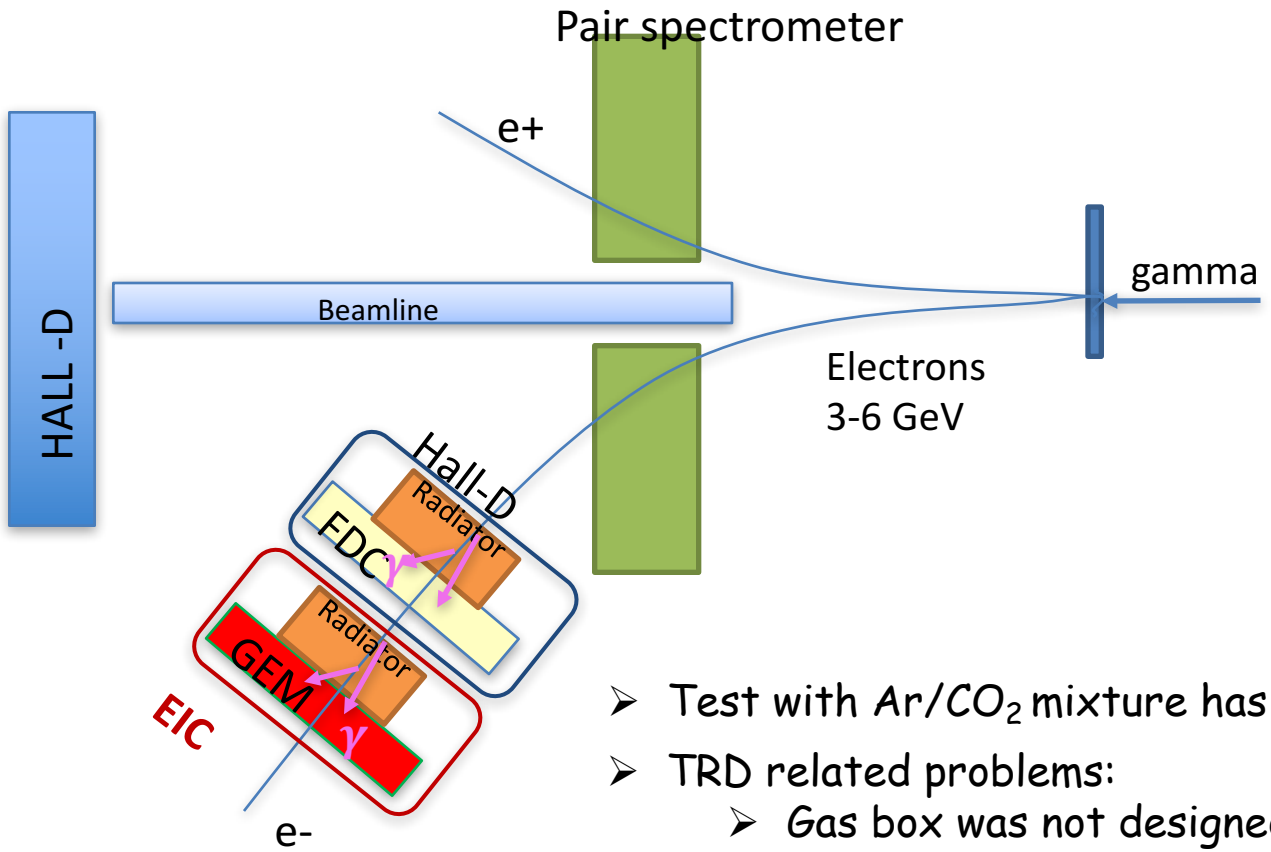


Drawing for the resistive divider



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

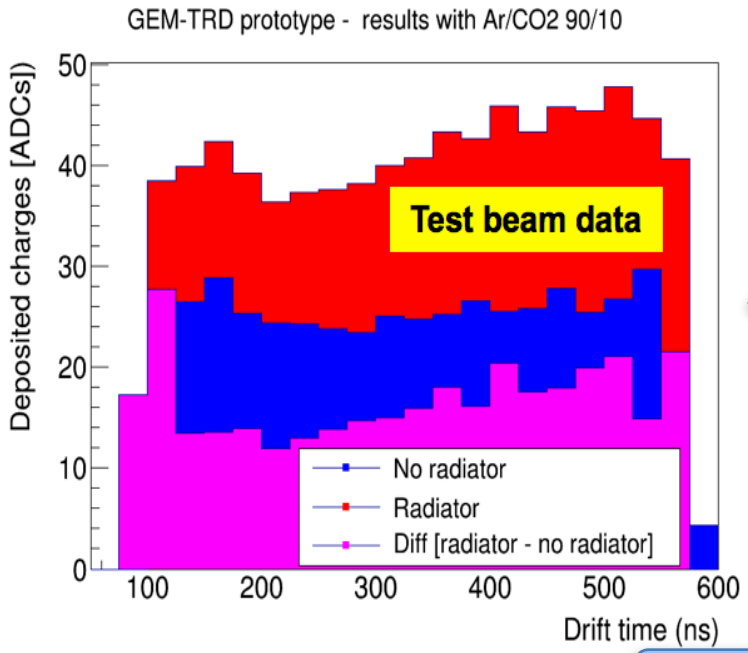
Test Setup at JLAB HALL-D



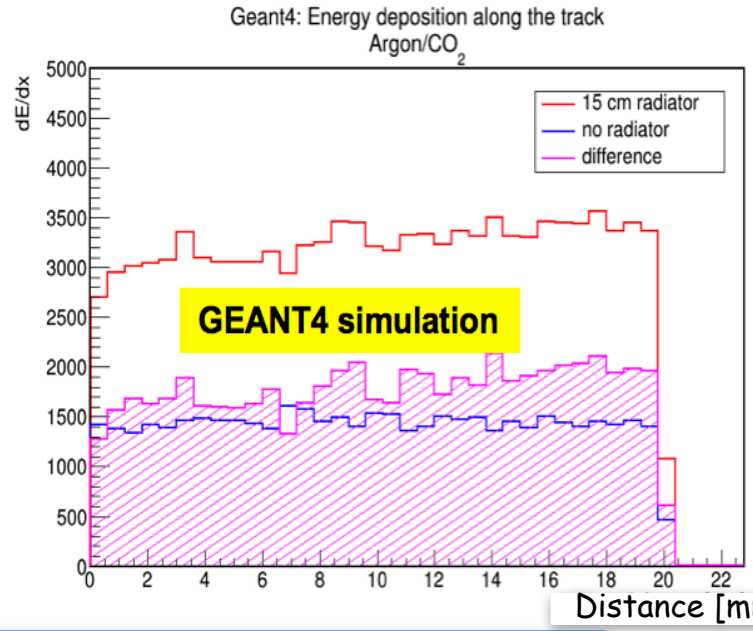
- Test with Ar/CO_2 mixture has been performed.
- TRD related problems:
  - Gas box was not designed for TRD
    => large gap in front window: filled with Xe, will absorb soft TR photons => radiator inefficiency.
  - Need to minimize a material at the entrance window
  - "existing" APV25 (only 600ns readout window) – ok for Ar-gas mixtures but not for Xe => need to apply voltages independently and/or new readout.

Yulia Furletova

FIRST TEST BEAM RESULTS WITH Ar/CO_2



beam

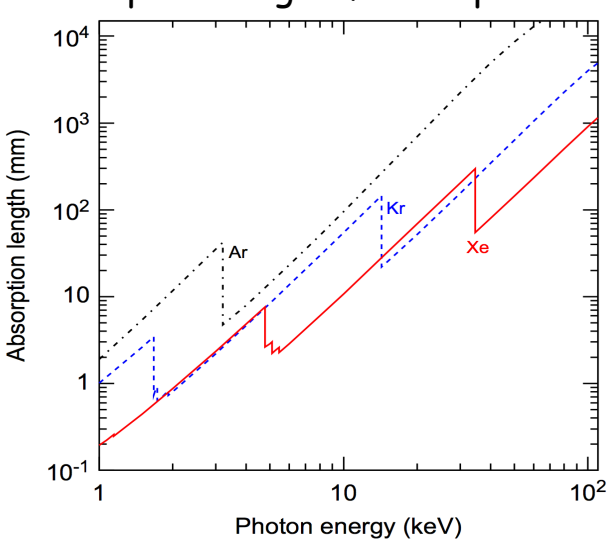


beam

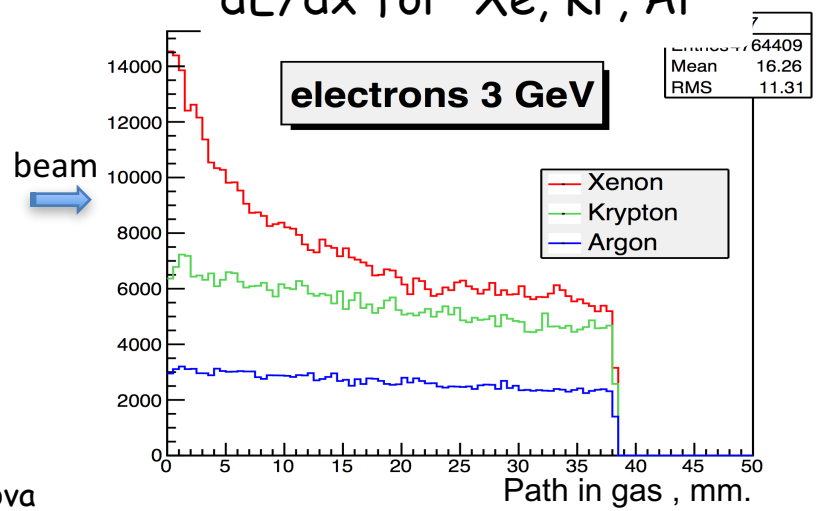
Expecting to see a larger effect with Xe

in Physics Research A 666 (2012) 130–147

absorption length for TR photons

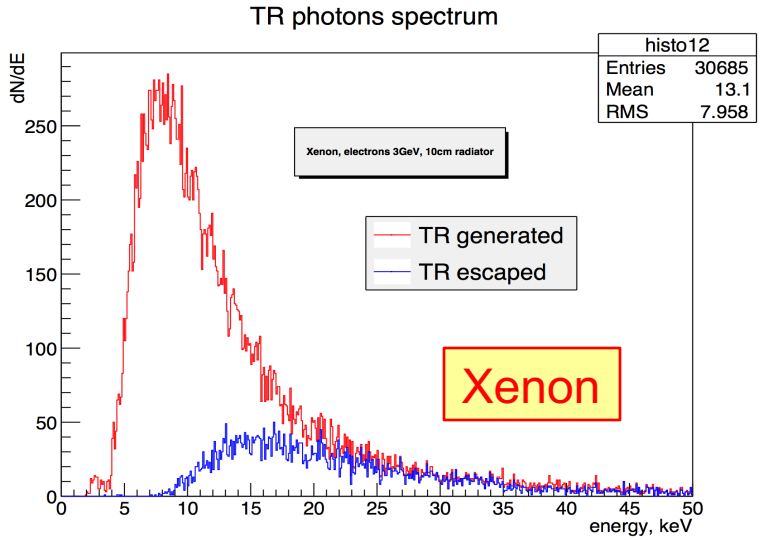


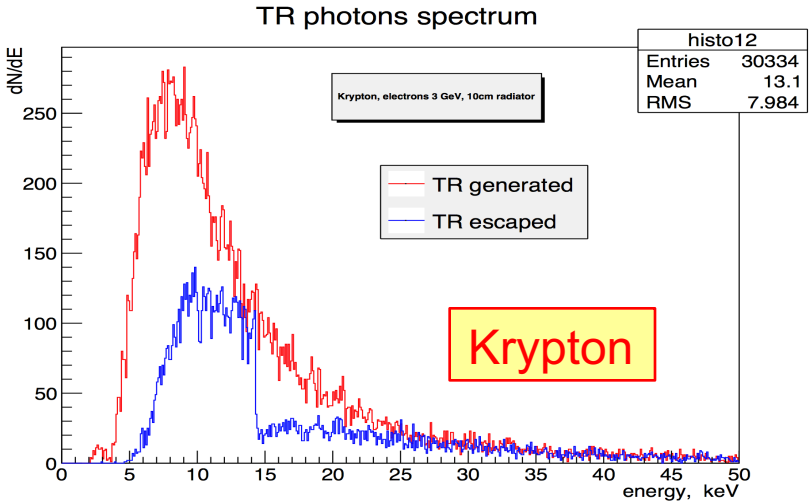
dE/dx for Xe, Kr, Ar

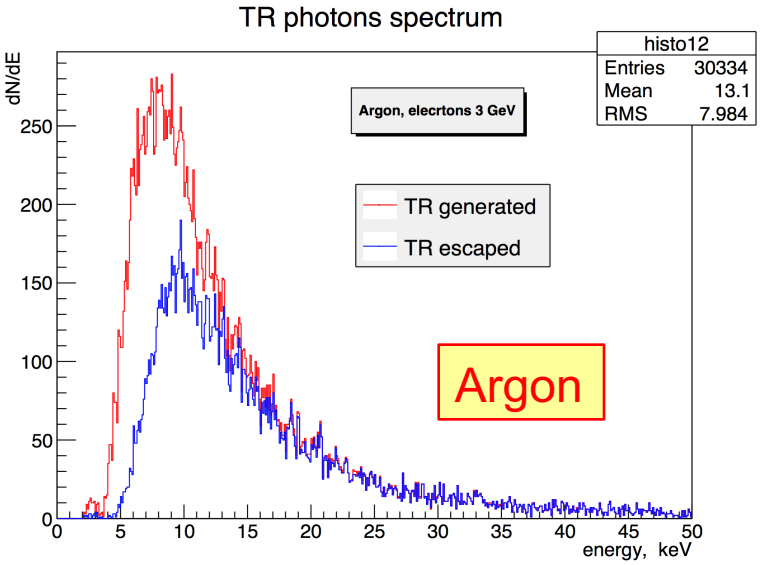


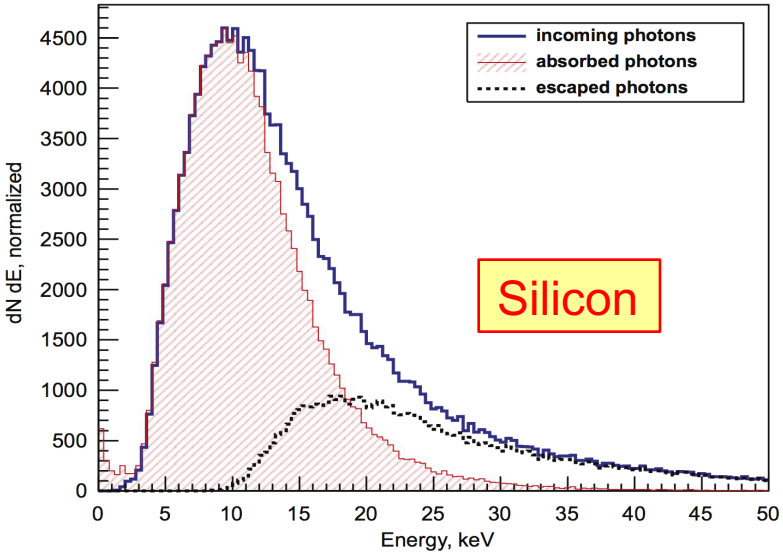
Yulia Furletova

TR absorption







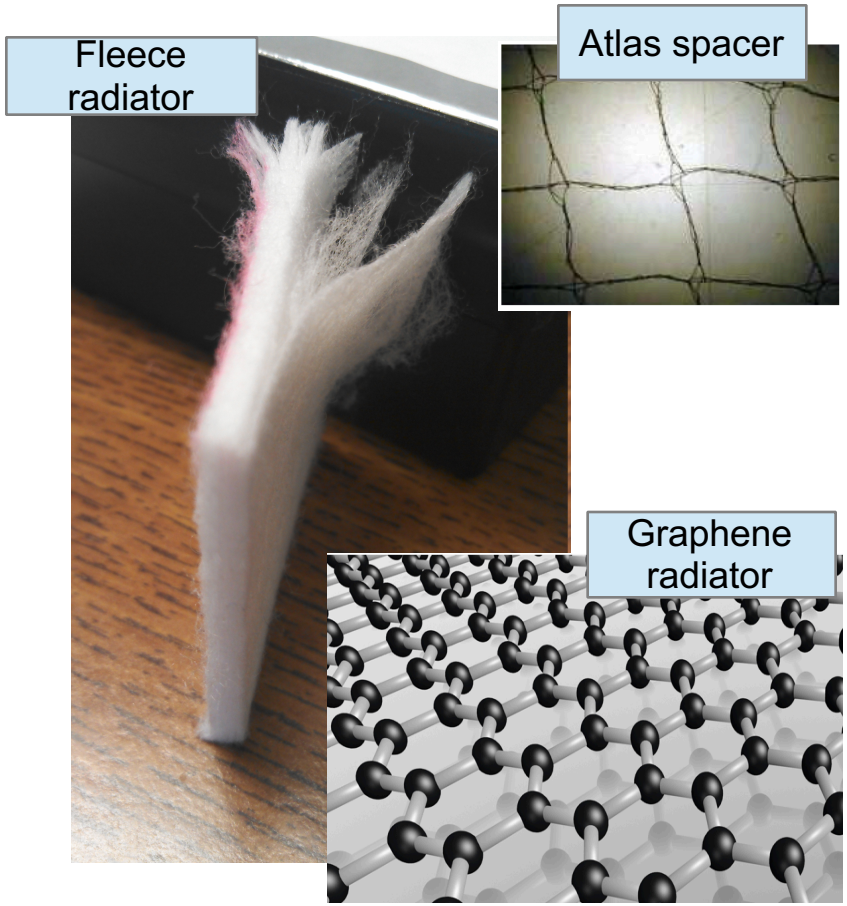


Radiators

- 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 is needed !!!



Proposal for R&D

- GEANT4 simulation of TRD setup with GEM detector
  - Estimate e/pi rejection factor for different configurations: layers, gases, electron efficiencies…

- Build and test two new GEM based transition radiation detectors and optimize their performance to work in a transition radiation detector operation: Prototype-I (standard) , Prototype-II (Cr) - to implement lessons learnt from the preliminary prototype

- Using the existing facility at JLAB Hall-D perform a test with "known" radiators (ATLAS, ZEUS, etc.) – "proof of principle"

- R&D and tests of other TR-radiators

- Front-end electronic / DAQ :
  - Test "existing" APV25 (problem: only 600ns readout window)
  - Test new DAQ with Flash ADCs

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

PROPOSAL FOR R&D

Proposed Budget for FY18

	Request	-20%	-40%
Xe/CO_2 (70/30) gas volume 54ft3 Pressure 820psig @70F	2x$ 8,000= $ 16,000	$ 8,000	$ 8,000
Gas system	$ 5,000	$ 4,000	$ 3,000
Detector prototype	$ 8,000 (2prototypes)	$ 8,000 (2 prototypes)	$ 6,000 (1 prototype)
Radiators	$ 2,000	$ 2,000	$ 1,000
Other material	$ 3,000	$ 3,000	$ 2,000
DAQ	$ 10,000	$ 10,000	$ 5,000
Travel*)	$ 16,000	$ 14,000	$ 13,000
Undergraduate student	$ 5,000	$ 5,000	$ 5,000
Total	$ 65,000	$ 54,000	$ 43,000
Overhead	$ 31,380	$ 25,400	$ 20,500
Summary	$ 96,380	$ 79,400	$ 63,500

Xe gas, Radiators, DAQ

Prototypes

Gas system

A summary table:

	Request	-20%	-40%
JLAB	$ 56,980	$ 43,120	$ 32,340
UVA	$ 23,800	$ 23,800	$ 21,800
Temple	$ 15,600	$ 12,480	$ 9,360
Total	$ 96,380	$ 79,400	$ 63,500

Summary

- Electron identification is very important for EIC physics
- Large hadron background is expected in the forward (Hadron-endcap) region
- High granularity tracker combined with TRD functionality could provide additional electron identification.
- Proposal for EIC detector R&D :
  Novel detector technology - GEM-TRD/T

Summary

- Electron identification is very important for EIC physics
- Large hadron background is expected in the forward (Hadron-endcap) region
- High granularity tracker combined with TRD functionality could provide additional electron identification.
- Proposal for EIC detector R&D :
  Novel detector technology - GEM-TRD/T

Thank you!

Backup

JLAB

	Request	-20%	-40%
Xe/CO_2 (70/30) gas volume 54ft3 Pressure 820psig @70F	2x $ 8,000= $ 16,000	$ 8,000	$ 8,000
Radiators	$ 2,000	$ 2,000	$ 1,000
DAQ	$ 10,000	$ 10,000	$ 5,000
Other material	$ 3,000	$ 3,000	$ 2,000
Travel	$ 6,000	$ 5,000	$ 5,000
Total	$ 37,000	$ 28,000	$ 21,000
Overhead (54%)	$ 19,980	$ 15,120	$ 11,340
Summary	$ 56,980	$ 43,120	$ 32,340

UVA

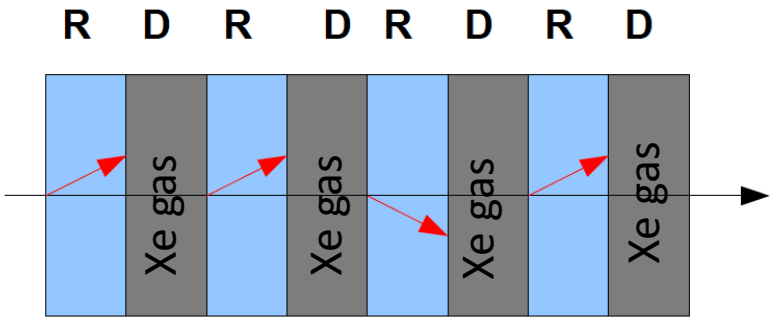
	Request	-20%	-40%
Detector prototype	$ 8,000 (2prototypes)	$ 8,000 (2prototypes)	$ 6,000 (1 prototype)
Undergraduate student	$ 5,000	$ 5,000	$ 5,000
Travel	$ 5,000	$ 5,000	$ 5,000
Total	$ 18,000	$ 18,000	$ 16,000
Overhead (58%) **)	$ 5,800	$ 5,800	$ 5,800
Summary	$ 23,800	$ 23,800	$ 21,800

**) Overhead is applicable to manpower and travel only

Temple

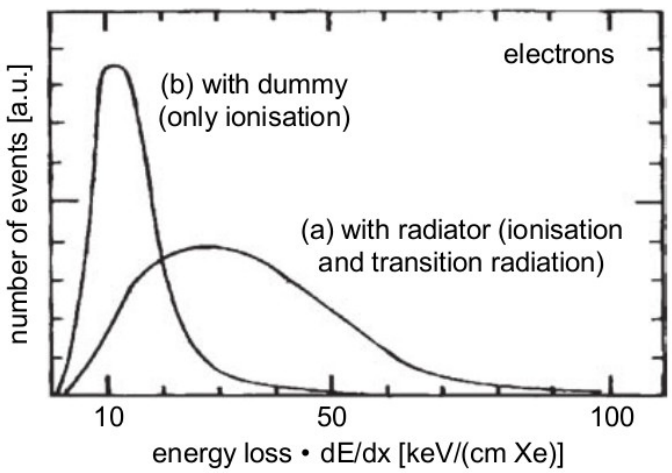
	Request	-20%	-40%
Gas system	$ 5,000	$ 4,000	$ 3,000
Travel	$ 5,000	$ 4,000	$ 3,000
Total	$ 10,000	$ 8,000	$ 6,000
Overhead (56%)	$ 5,600	$ 4,480	$ 3,360
Summary	$ 15,600	$ 12,480	$ 9,360

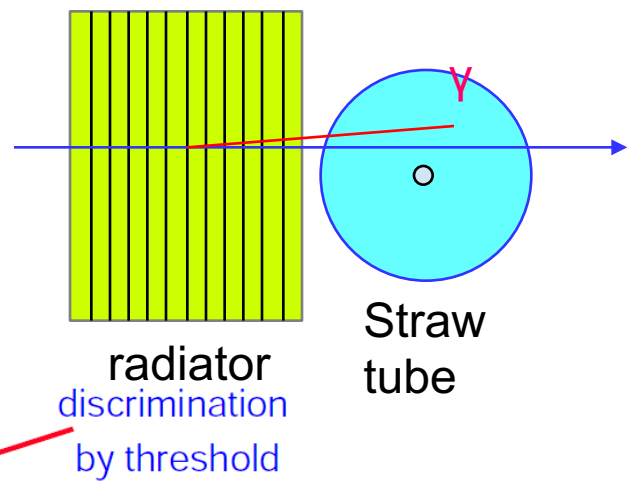
Xe -gas detectors

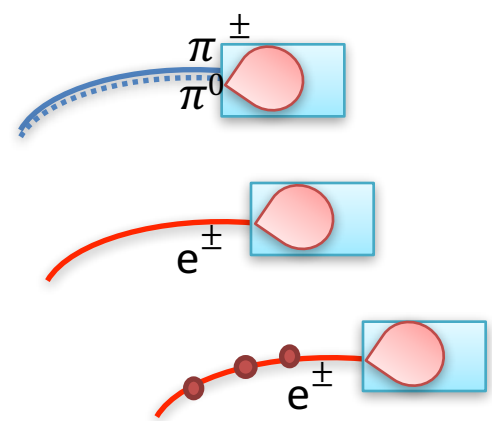


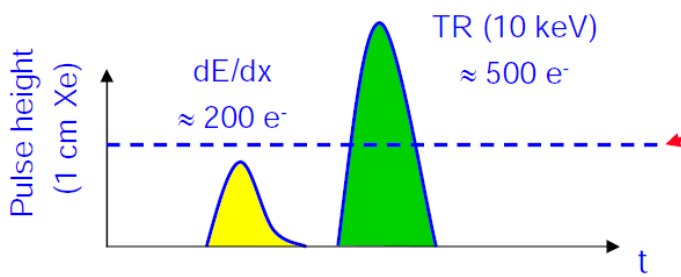
- Stack of radiators and detectors (sandwich)
- For "classical" TRD (straw, MWPC) gas is needed for better absorption of TR photons: high Z required => Xenon gas (Z=54)

- 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).



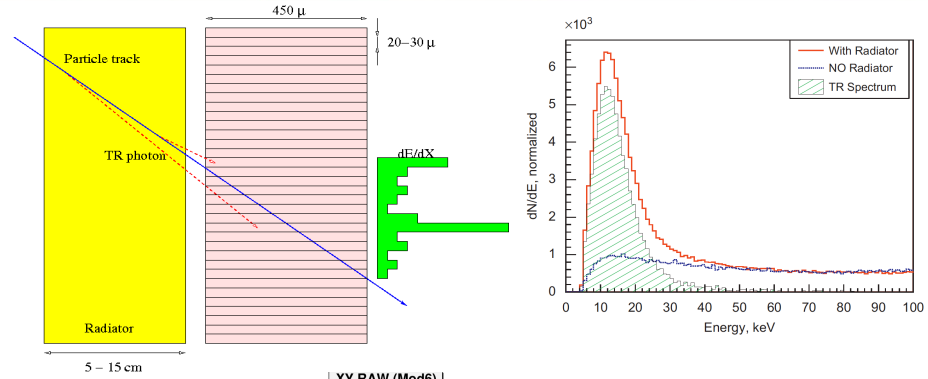




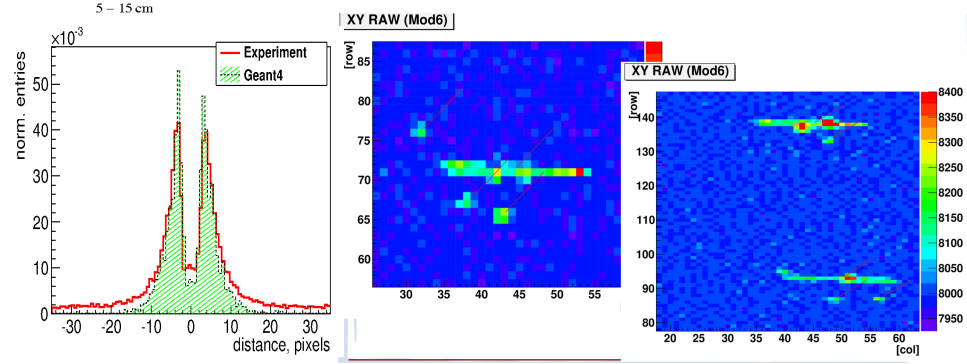


Silicon pixel TRD

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



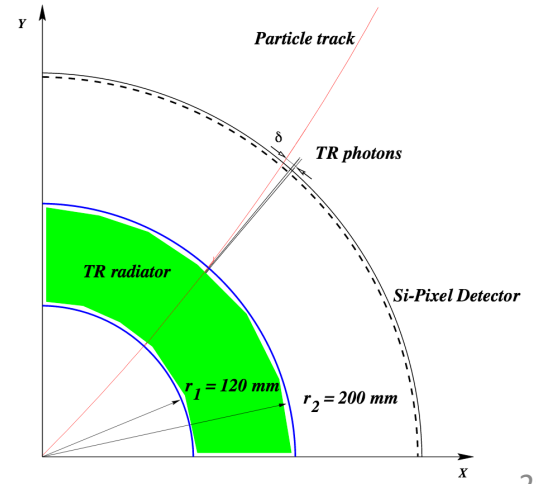
- **DEPFET silicon pixel detector**
  - Low noise, high S/N with 450 μm thick fully depleted bulk(sensitive area), pixel size – 20x20μm^2 .
  - TR photons are clearly visible and separated from track by a few pixels!



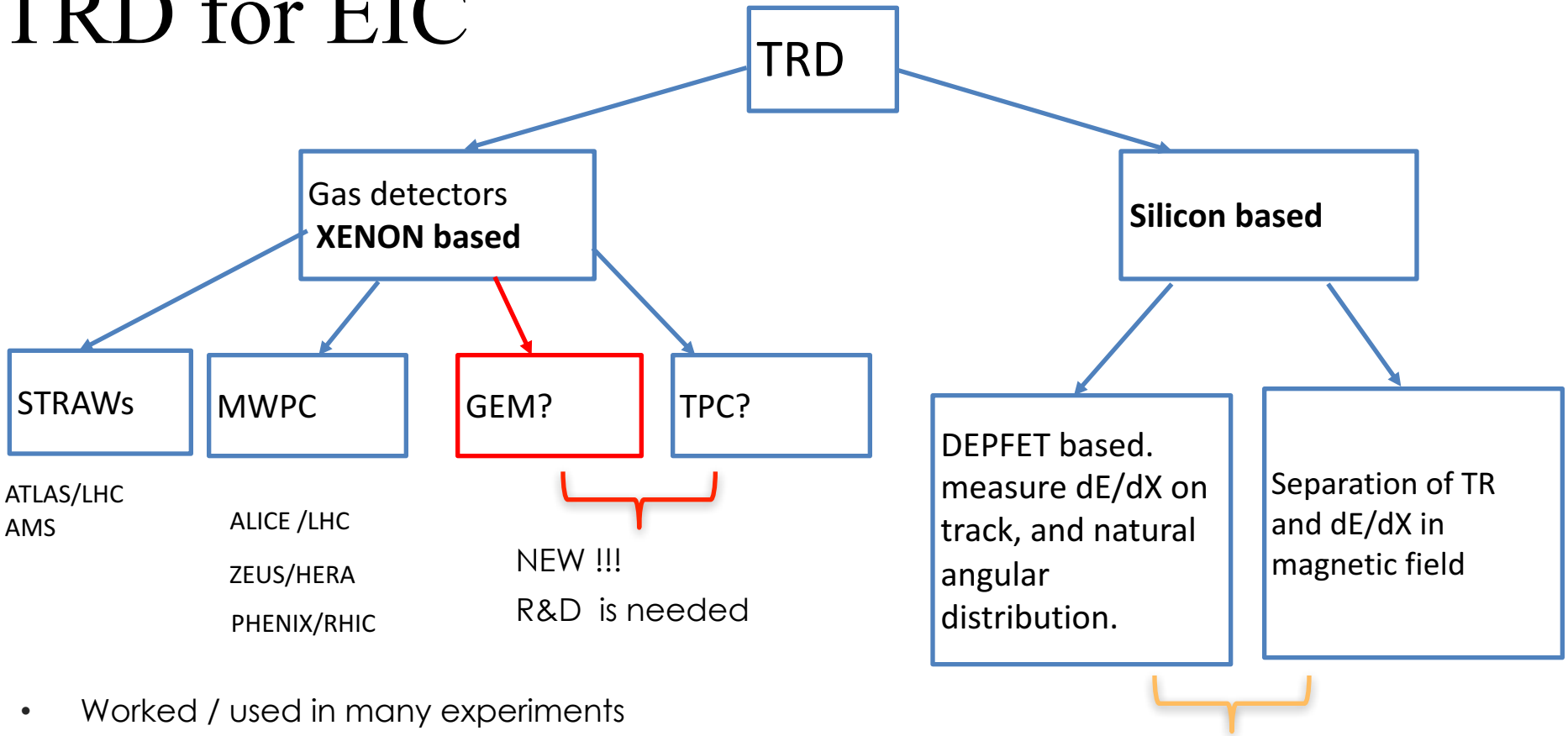
"New transition radiation detection technique based on DEPFET silicon pixel matrices", J.Furletova, S. Furletov, NIM-A 2010, http://dx.doi.org/10.1016/j.nima.2010.06.342
"Geant4 simulation of transition radiation detector based on DEPFET silicon pixel matrices", J. Furletova,S. Furletov, DOI: 10.1016/j.nima.2012.05.009

- **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?