Transition Radiation Detector for GlueX

Test with Argon

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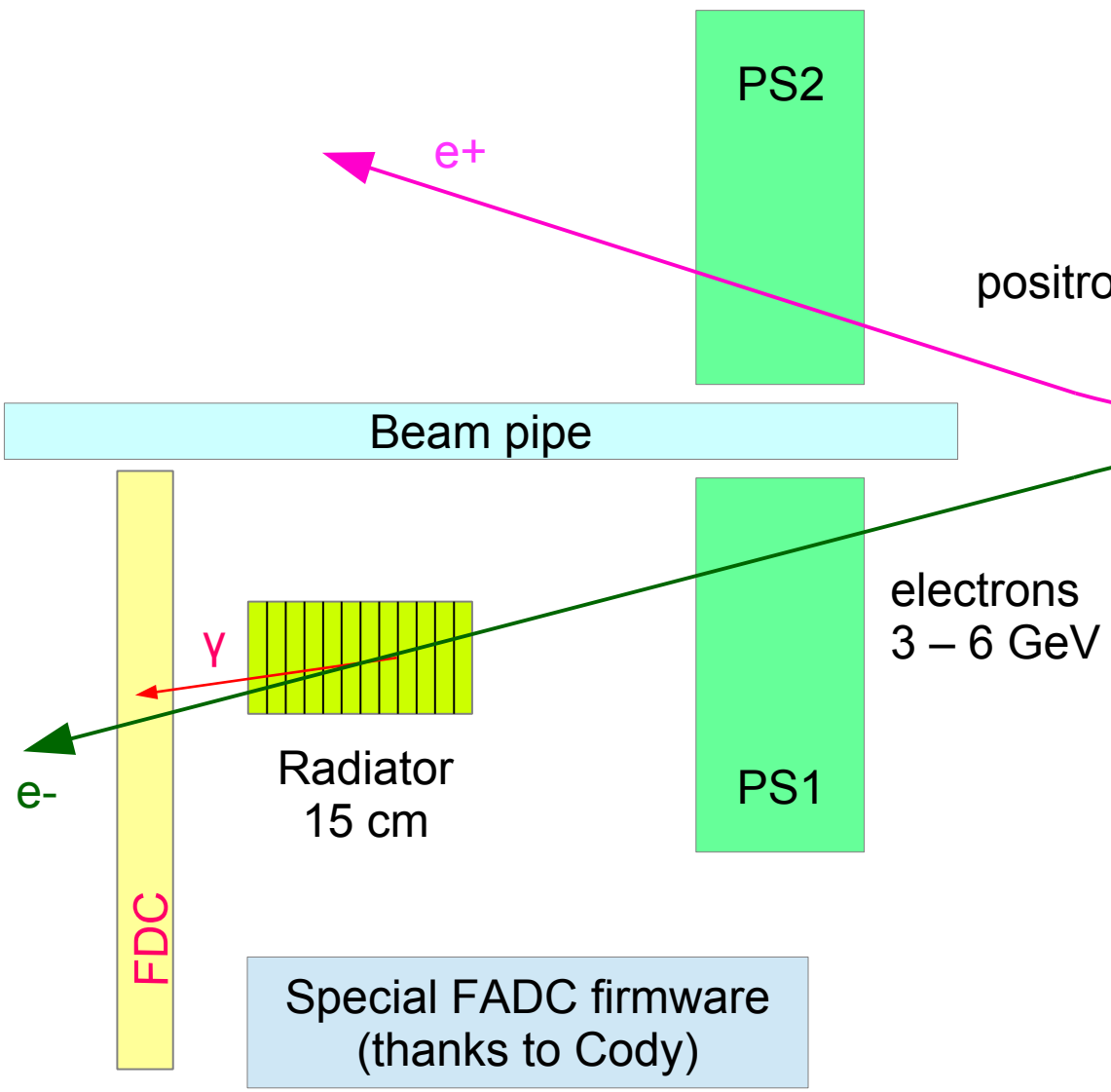
GlueX Collaboration Meeting

Feb 19, 2016

Outline

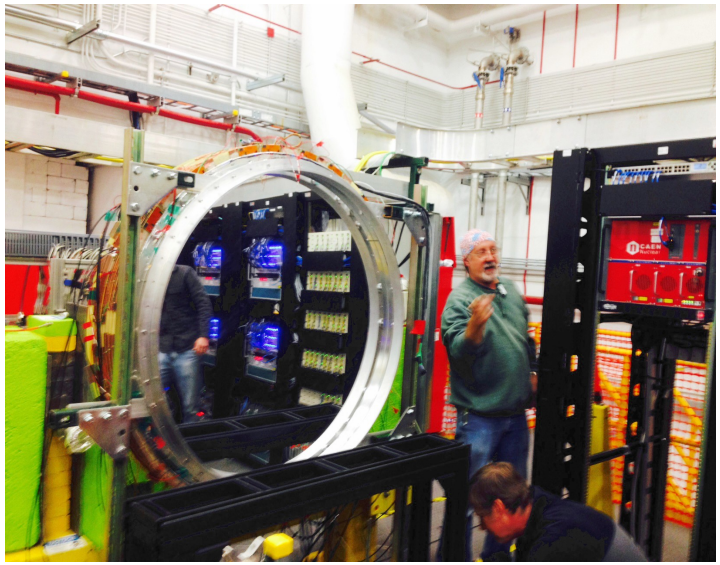
- Test setup in Hall D
- Monte Carlo simulation
- First results
- Outlook

TRD/FDC test setup in Hall D

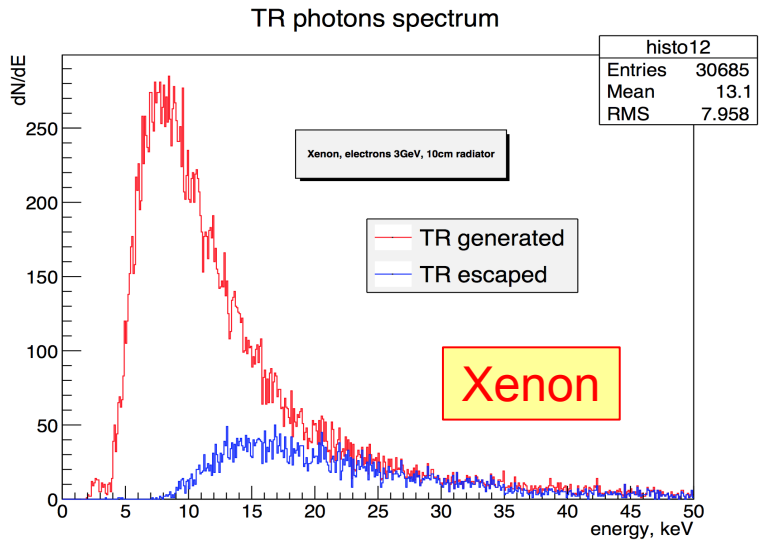


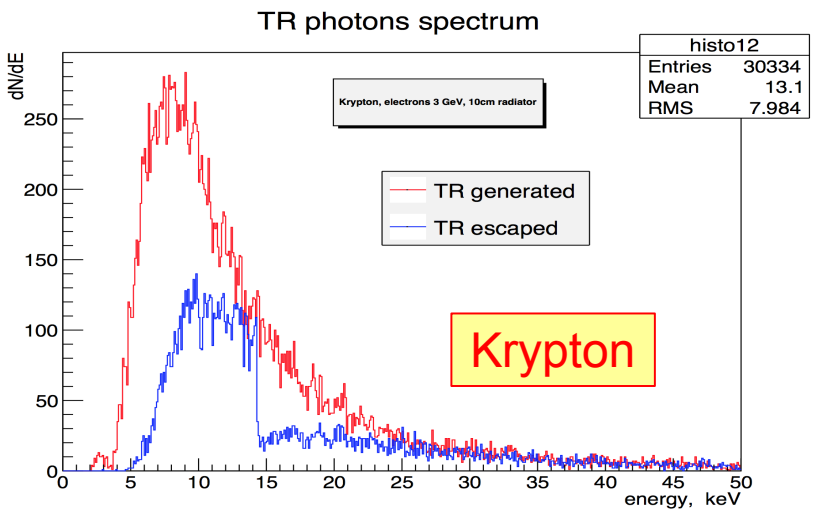
Test with PS trigger
(thanks Sasha for help)

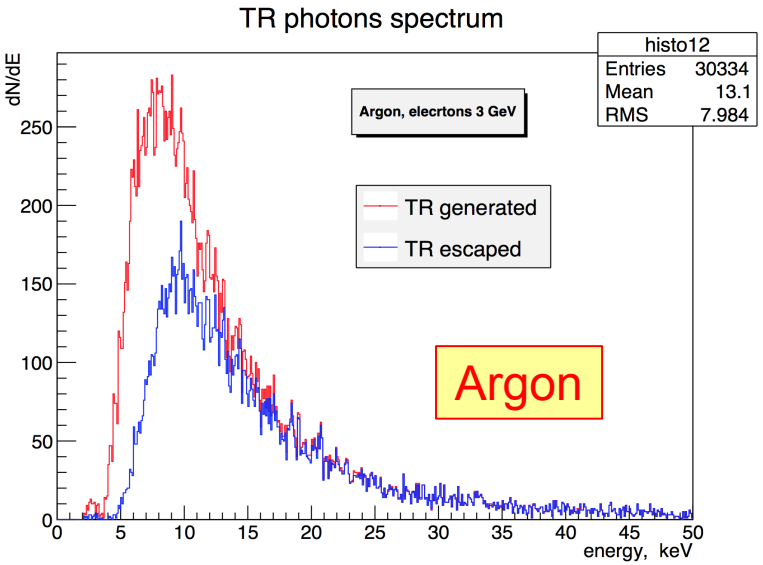
Special FADC firmware
(thanks to Cody)

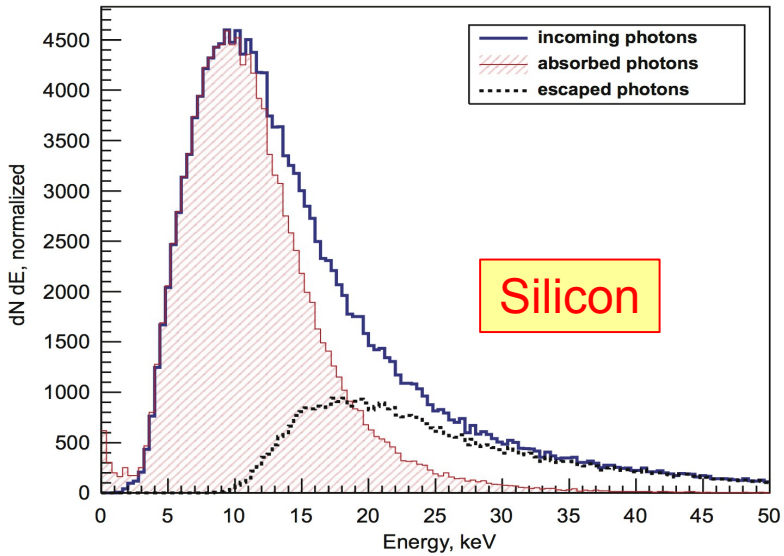


TR absorption spectrum

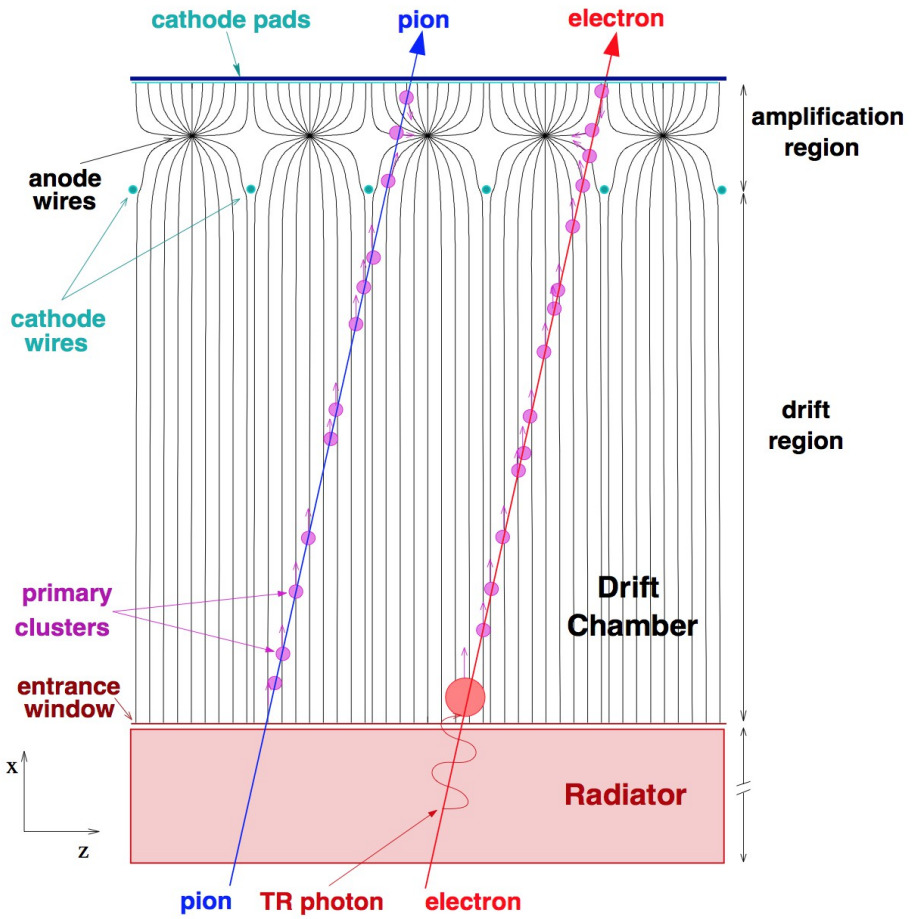






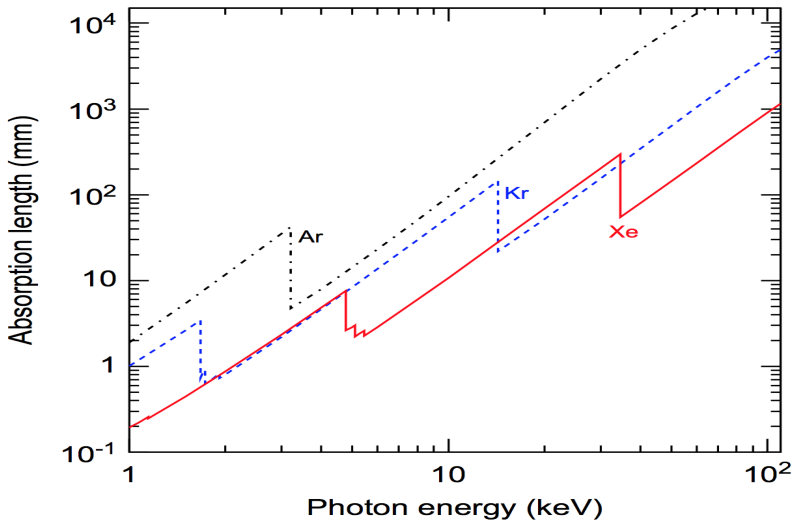


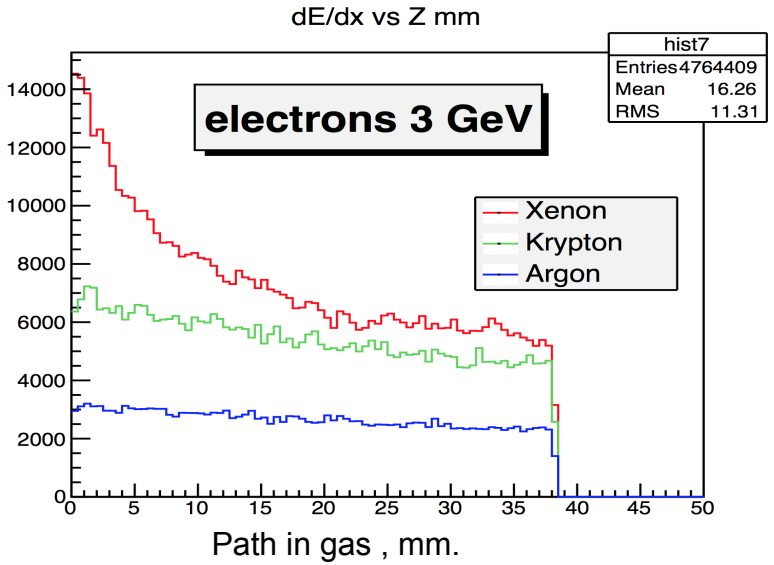
TR absorption length in Xe,Kr,Ar



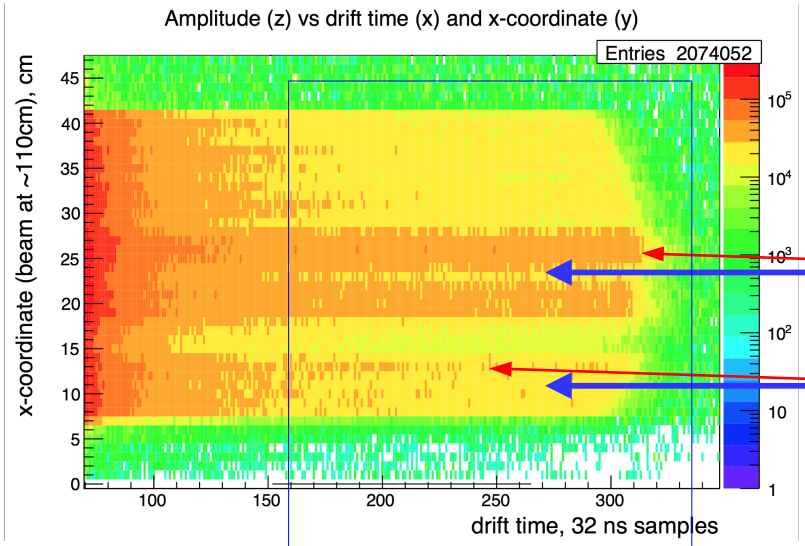
ALICE TRD

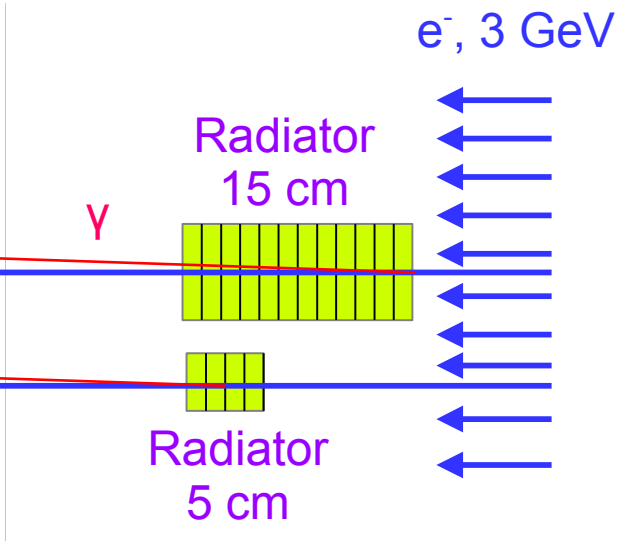
in Physics Research A 666 (2012) 130–147

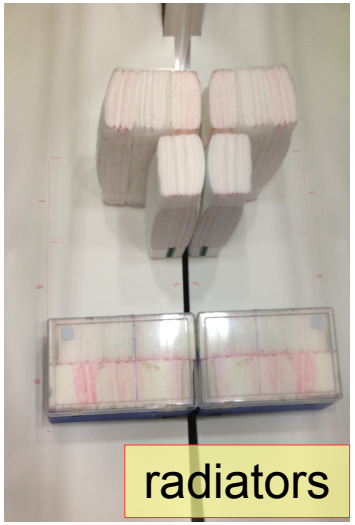


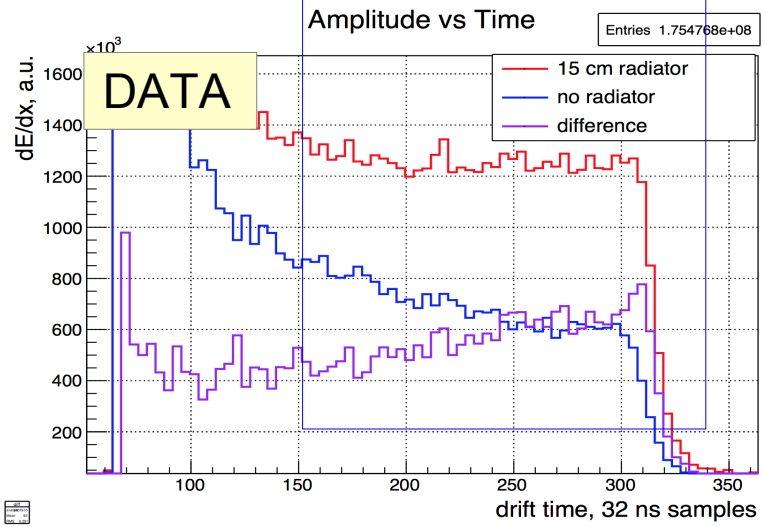


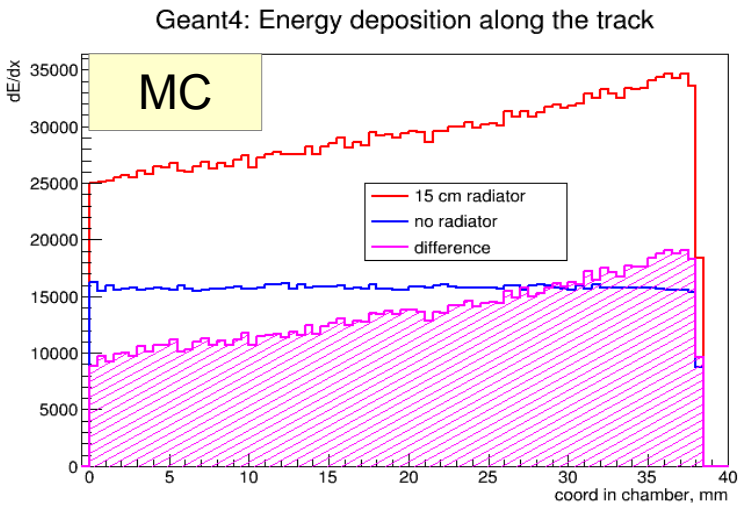
TR absorption in Argon



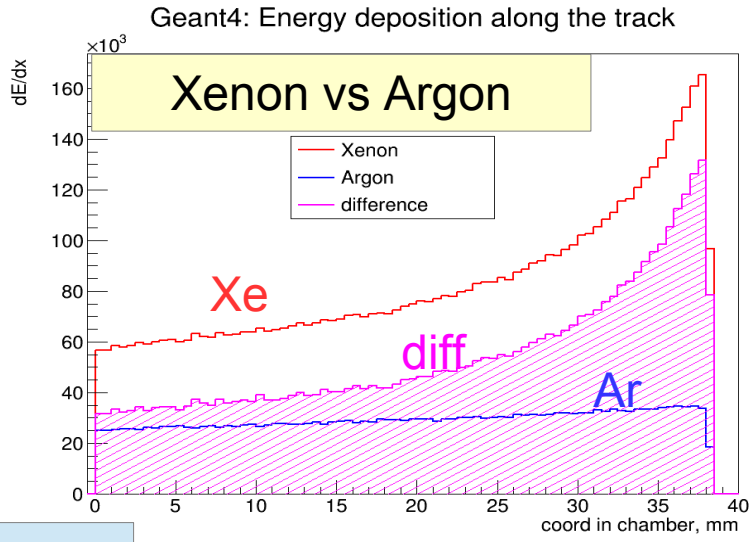




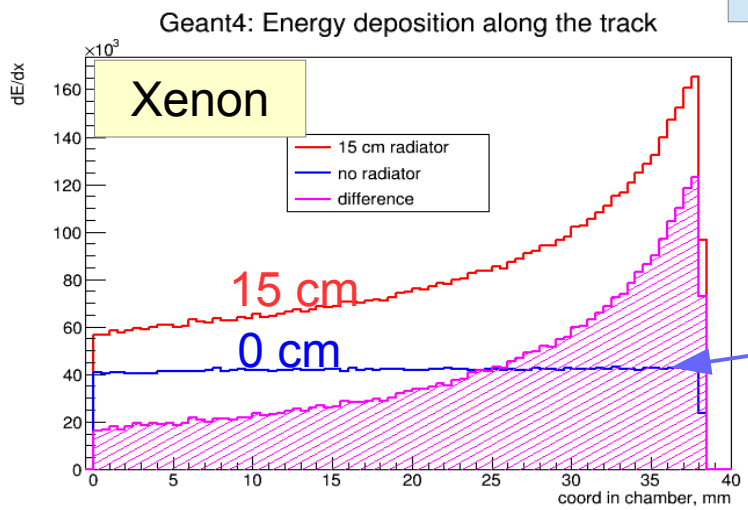


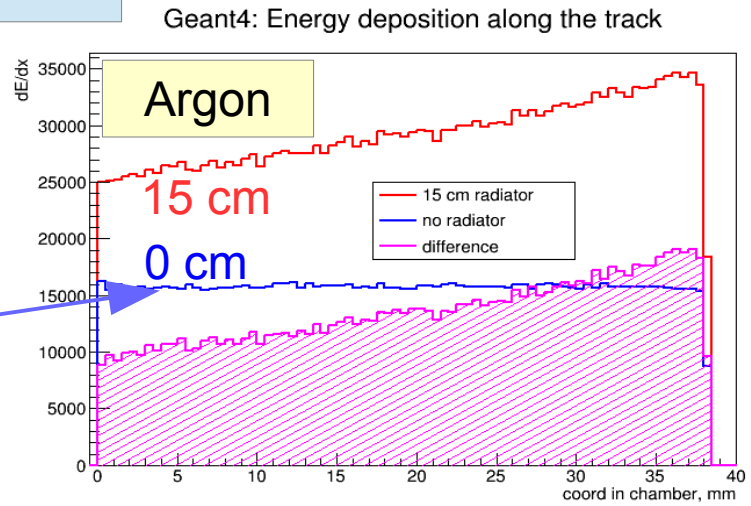


Geant4: TR absorption: Ar vs Xe



Electrons, 3 Gev





Outlook

- Test TRD in Hall D with Argon consistent with MC
- Next step would be test with Xenon

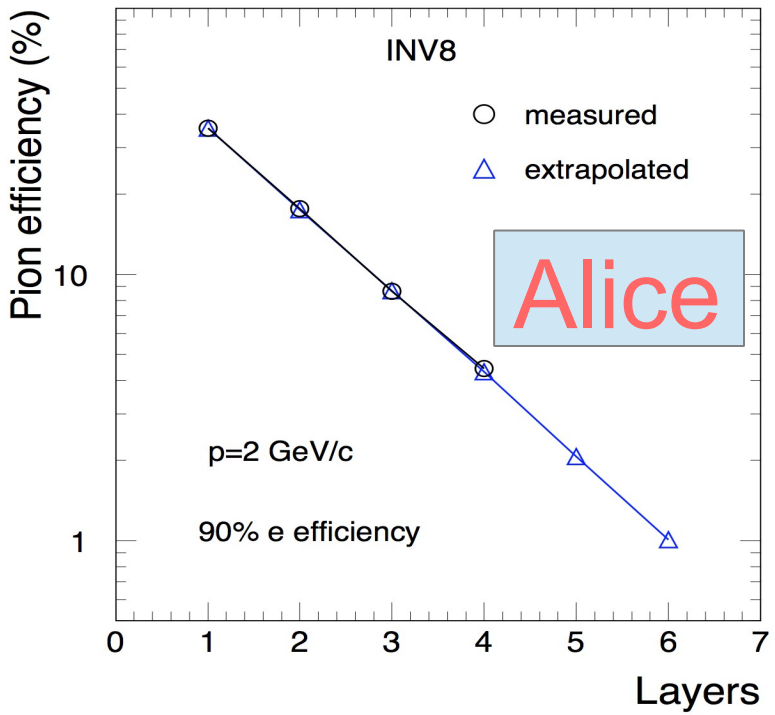
MC calculation , TRD e / pi rejection

electron efficiency	90%		72%
N mod	1 module	3 modules	3 modules
Xenon	10	450	1600
Krypton	5.7	80	360
Argon	3.5	32	160

Backup slides

What rejection we can expect ?

- Performance of TRD can be parametrized as a function of a detector length.



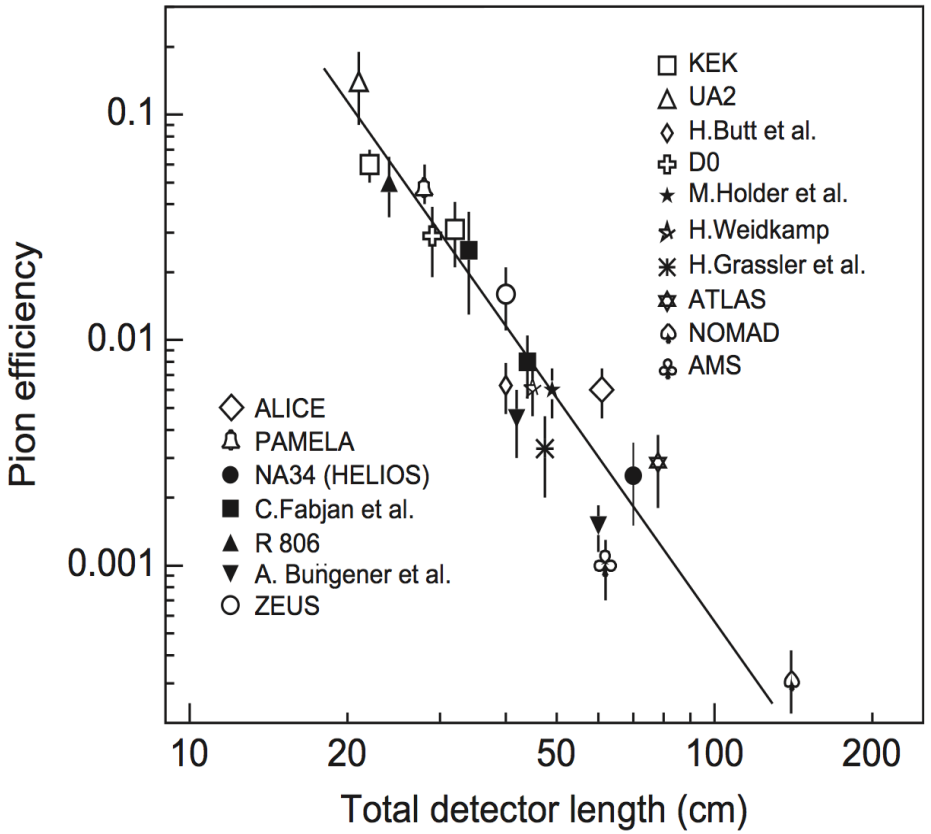


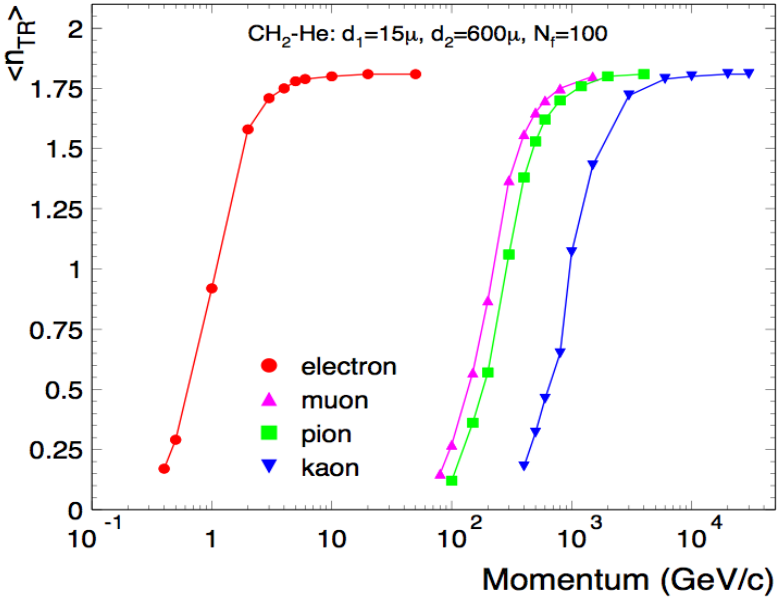
Fig. 11. TRD rejection power as a function of the total length of the detector for various high-energy (astro-)particle experiments (figure from [46]). The line is drawn to guide the eye.

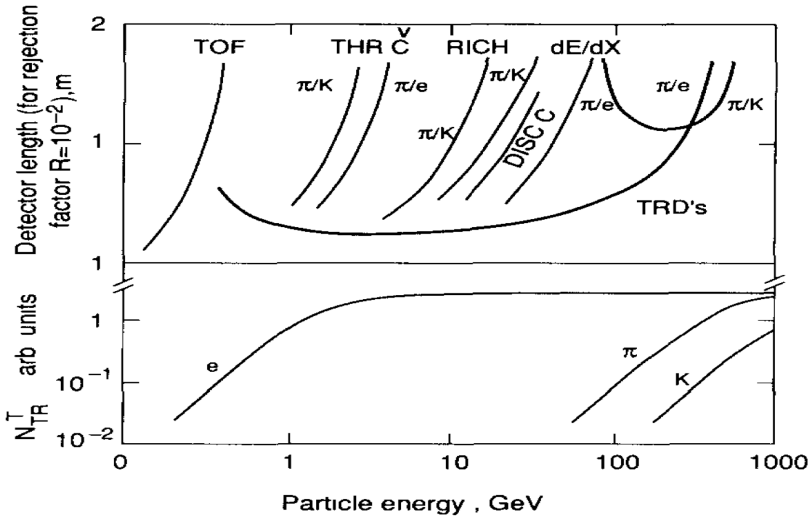
[46] K. Nakamura, et al., Particle Data Group, Journal of Physics G 37 (2010) 075021.

Motivation / detector

- Transition Radiation Detectors (TRD) has the attractive features of being able to separate particles by their gamma factor.
- e/π separation in high γ region, where other methods are not working anymore.
- Identification of the charged particle “on the flight”: without scattering, deceleration or absorption.
- Application of TRD in physics experiments:

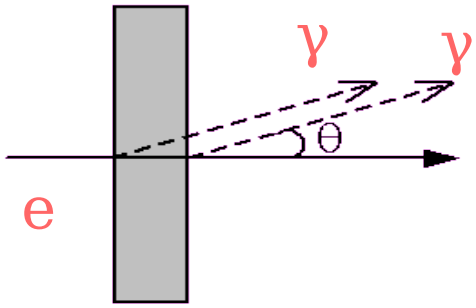
  ZEUS, H1, HERMES at HERA (DESY), D0, PHENIX, ATLAS, ALICE...
- TRD in space missions – AMS, PAMELA.



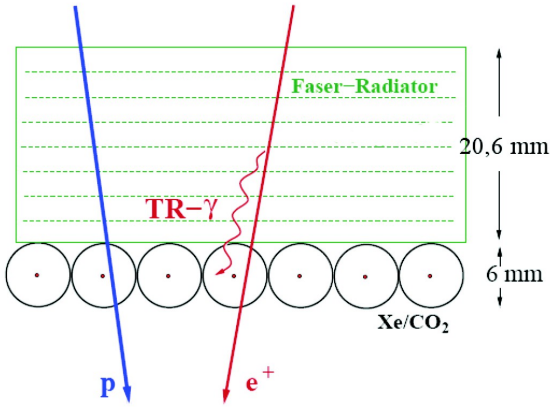


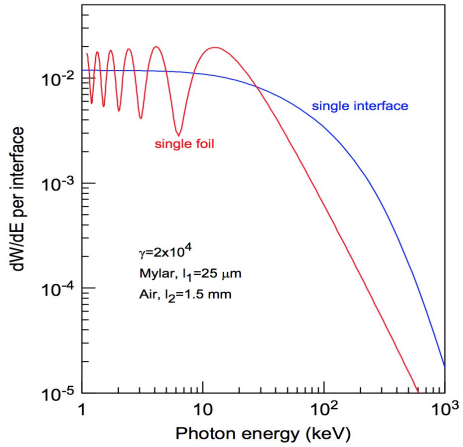
Transition radiation

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



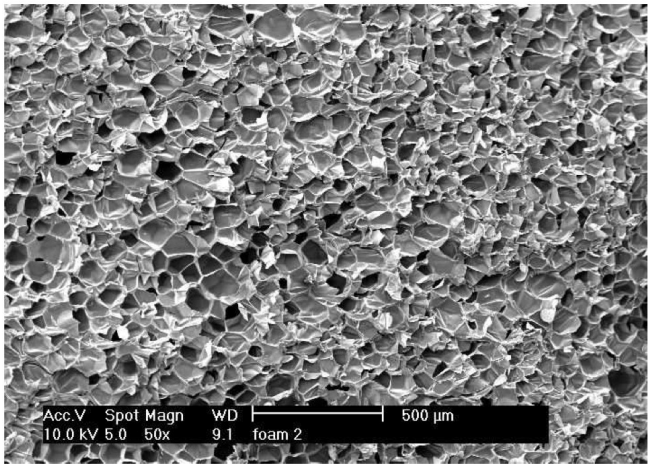
- Due to electrodynamic nature of TR the probability to emit one photon per boundary is order of α~1/137
- Therefore a multilayer dielectric radiators are used to increase the transition radiation yield, typically few hundreds of mylar foils.





From single foil to radiator

- Another possible materials for radiators are polyethylene foam and fibers (fleece)



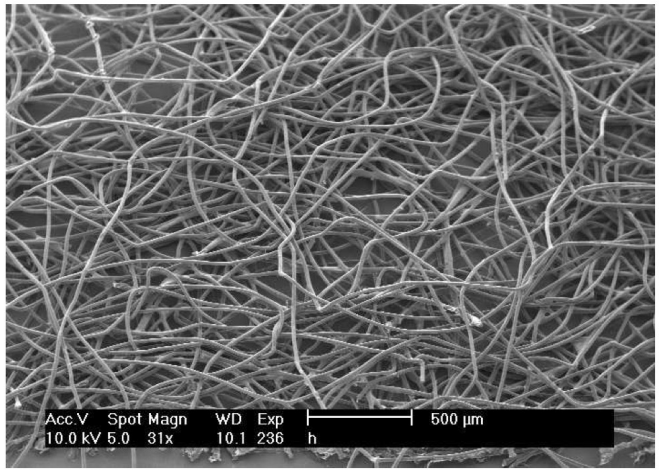
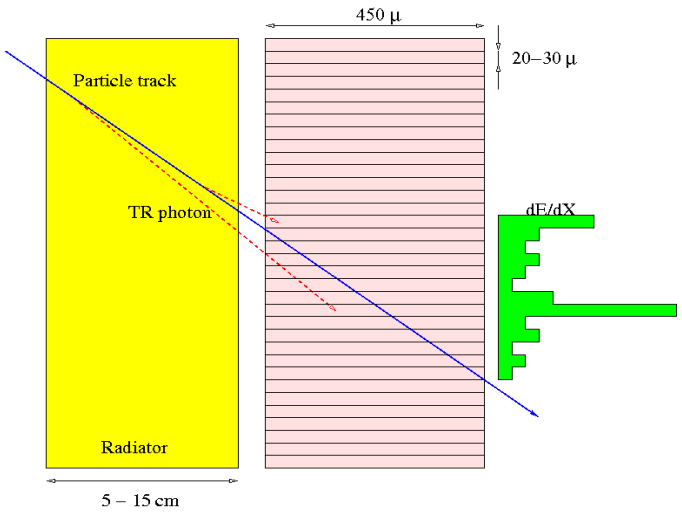


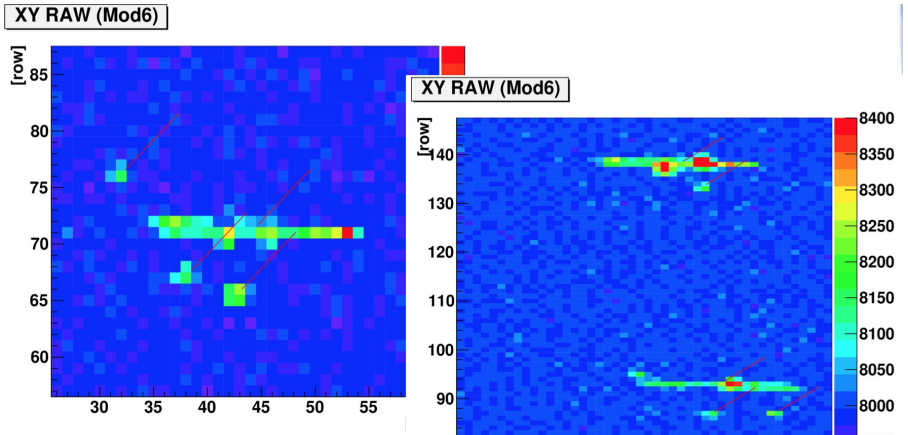
Figure 2: Electron microscope images of a polymethacrylimide foam (Rohacell HF71)(left) and a typical polypropylene fiber radiator (average diameter $\approx$ 25 μm) (right) [52].

[52] A. Andronic et al. (ALICE collaboration), Nucl. Instr. and Meth. in Phys. Res. A **558**, 516 (2006).

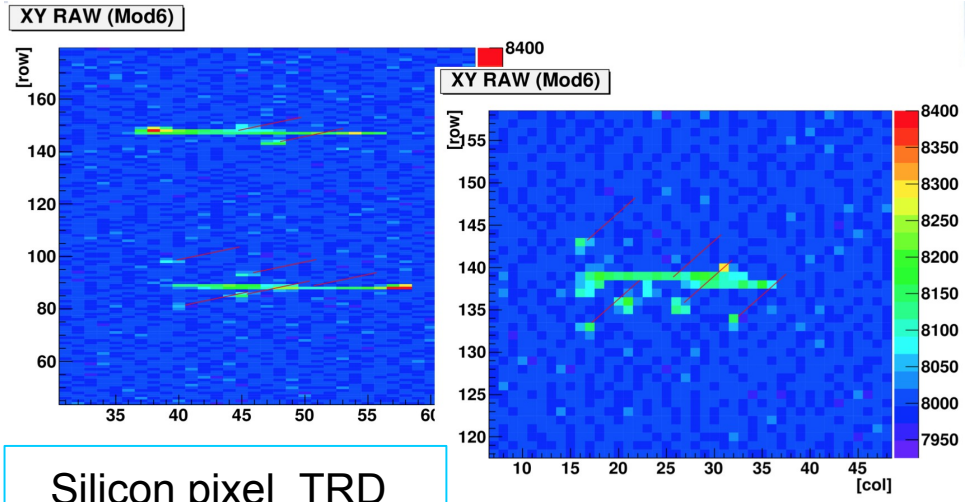
TR detection



- Silicon pixel detector , 450 μ thick. (pixel size – 20x20μ)
- The electrons energy is 5 GeV (DESY testbeam)
- Radiator thickness 15 cm (fleece)
- TR photons are clearly visible and separated from track by a few pixels !
  - red lines shows the center of found TR clusters



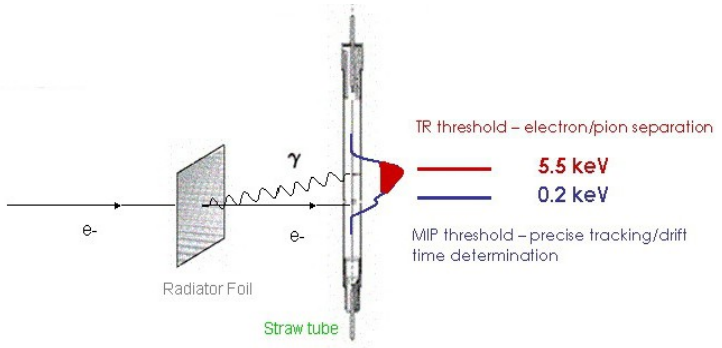
Silicon pixel TRD

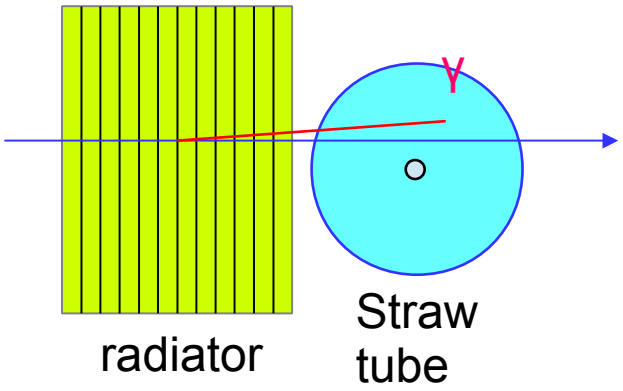


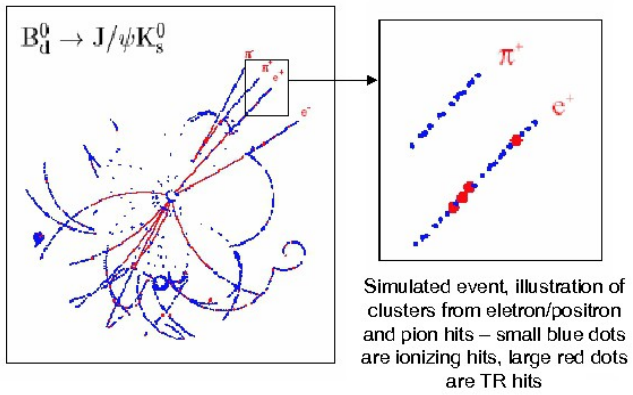
Silicon pixel TRD

TRD principle : ATLAS

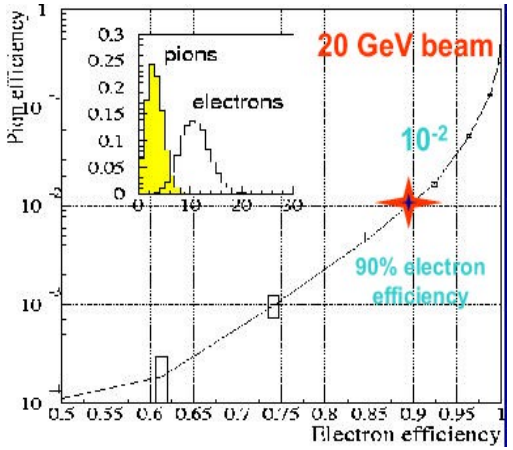
- Typically in high energy physics TRD are used for electron identification and to reject hadron background.
- ATLAS TRT uses proportional gas chambers (straws) filled with Xenon gas mixture:
  - dE/dx +TR, Cluster discrimination by threshold method.







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



TRD in experiments

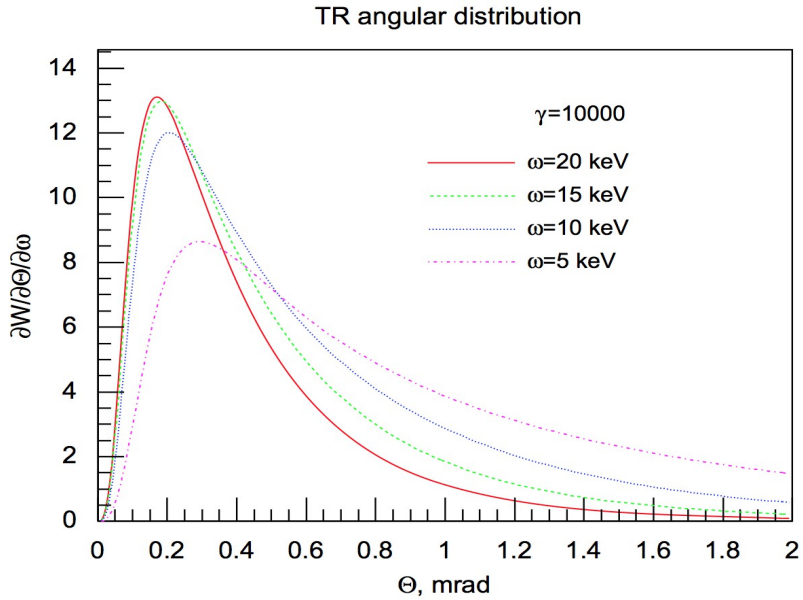
Experiment	Radiator (x,cm)	Detector (x,cm)	Area (m^2)	N	L (cm)	N. chan.	Method	π_{rej}
HELIOS	foils (7)	Xe-C_4H_{10} (1.8)	0.5	8	70	1744	N	2000
H1	foils (9.6)	Xe-He-C_2H_6 (6)	1.8	3	60	1728	FADC	10
NA31	foils (21.7)	Xe-He-CH_4 (5)	4.5	4	96	384	Q	70
ZEUS	fibres (7)	Xe-He-CH_4 (2.2)	3	4	40	2112	FADC	100
D0	foils (6.5)	Xe-CH_4 (2.3)	3.7	3	33	1536	FADC	50
NOMAD	foils (8.3)	Xe-CO_2 (1.6)	8.1	9	150	1584	Q	1000
HERMES	fibres (6.4)	Xe-CH_4 (2.54)	4.7	6	60	3072	Q	1400
kTeV	fibres (12)	Xe-CO_2 (2.9)	4.9	8	144	~10 k	Q	250
PAMELA	fibres (1.5)	Xe-CO_2 (0.4)	0.08	9	28	964	Q,N	50
AMS	fibres (2)	Xe-CO_2 (0.6)	1.5	20	55	5248	Q	1000
PHENIX	fibres (5)	Xe-CH_4 (1.8)	~~50~~	~~6~~	~~4~~	~~43 k~~	~~FADC~~	~~~300~~
ATLAS	fo/fi (0.8)	Xe-CF_4-CO_2 (0.4)	31	36	51-108	425 k	N,ToT	100
ALICE	fi/foam (4.8)	Xe-CO_2(3.7)	**126**	6	52	**1.2 mil.**	FADC	200

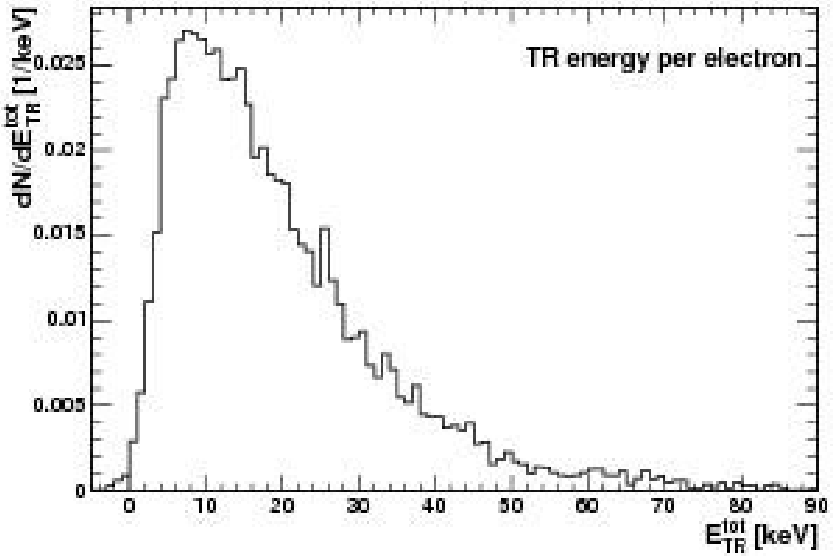
?

all radiator material CH_2

TR features

- X-ray TR has remarkable features:
- 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

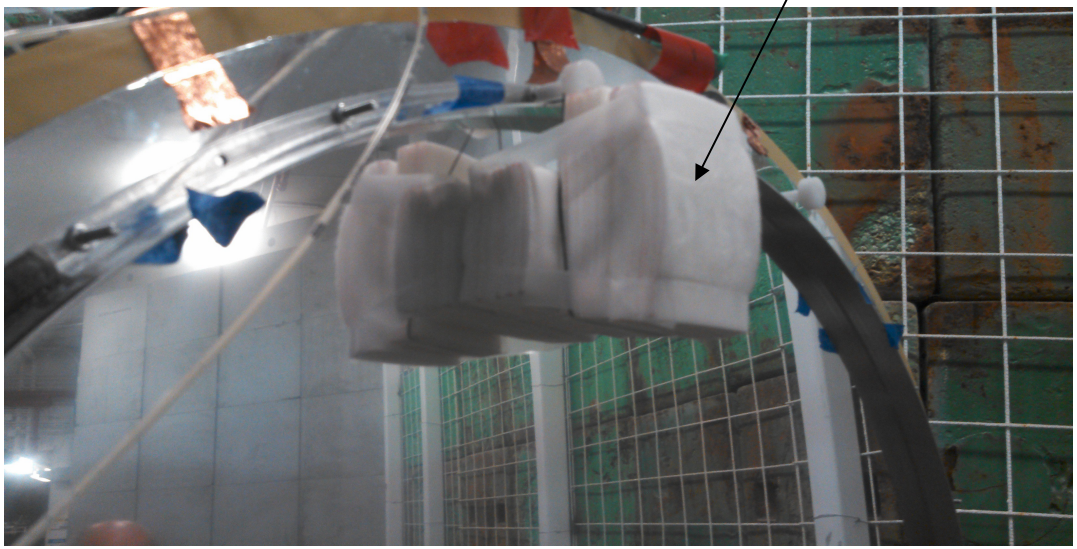




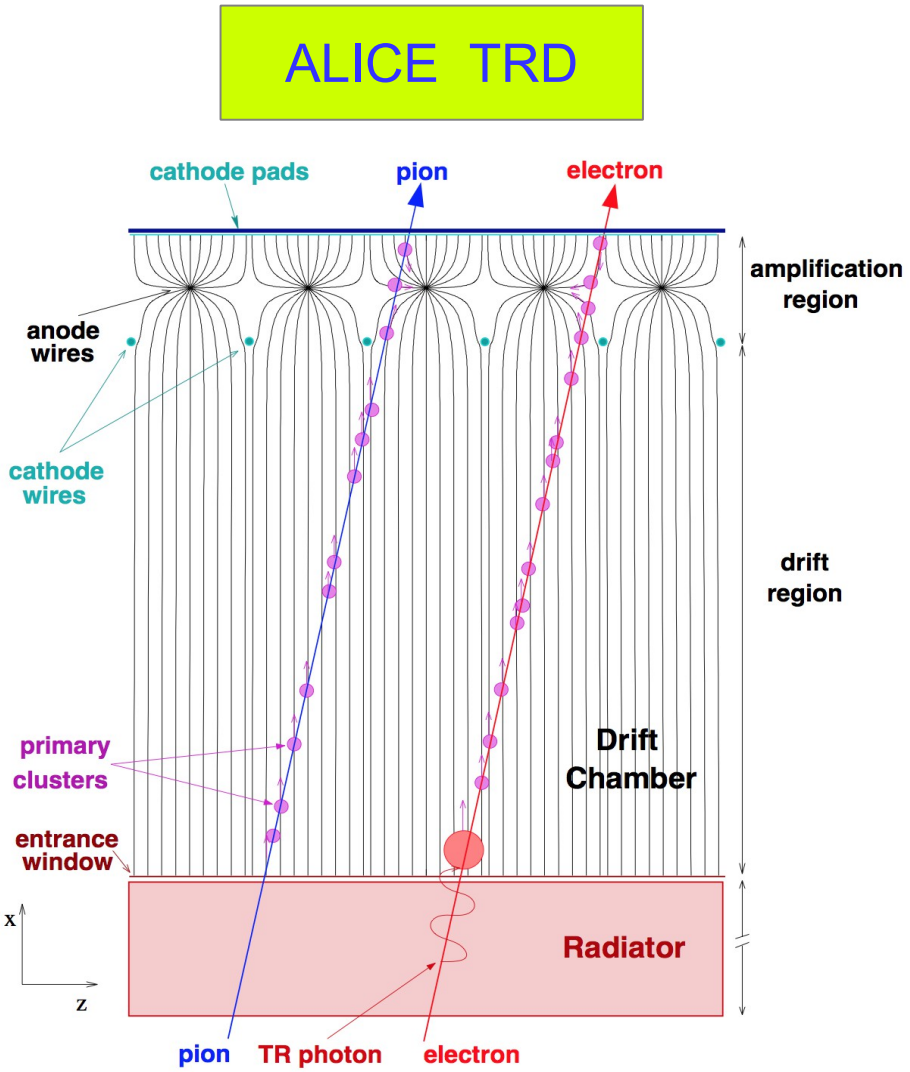
Radiator

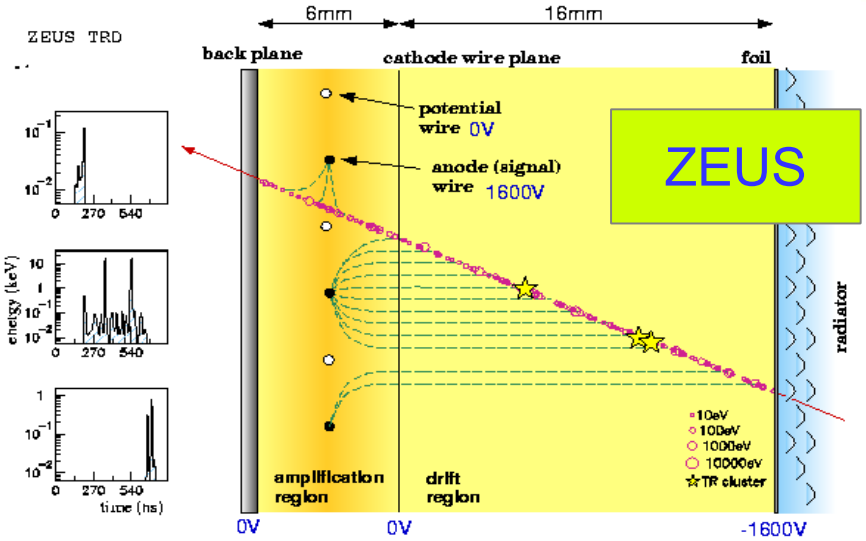
- The theory of transition radiation predicts that the best radiator is a stack of regular foils:
  - 20-30μ mylar foils and 200-300μ air gap.
- ATLAS use foils and spacer between foils to provide air gap.
- ZEUS and many other experiments use fleece radiators.
- Bottom picture shows FDC with fleece radiator in front

Atlas spacer



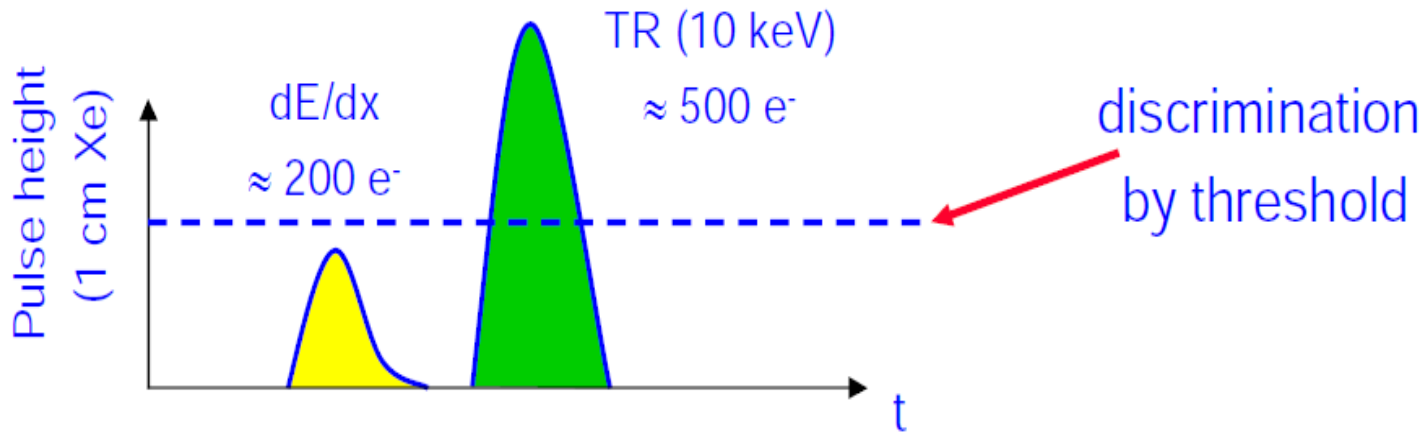
TRD with wire chambers





TR detection methods

1) Cluster counting method
2) Total energy deposition
3) dE/dx along track (FADC)



TR absorption in Argon