Considerations for the RICH detector for CEPC

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Outline

- Motivation
- Introduction to technology for PID
- Pre-design of the RICH detector
  - Structure
  - Consideration of a prototype
  - Photon detector
  - Comparison of RICHs using C4F10 gas radiator.
- Micromegas R&D at USTC
  - THGEM + Mmegas hybrid structure
  - Try to reduce the readout channels
- Summary

Motivation

Z pole measurement is one of the goals of CEPC !

The CEPC is expected to collect $10^{10\text{-}12}$ Zs (in CEPC's pre-CDR).

Benefits from high-stat z pole data:

- Precision test of SM & new physics searches
- Fragmentation functions & QCD
- Heavy flavor physics, spectroscopy & new hadrons
- τ-lepton physics
- others

$e^-e^+ \to Z^0 \to l^-l^+$

$e^-e^+ \to Z^0 \to q^-q^+$

Hadron identification is crucial!

And a dynamic range of GeV to 40 GeV for κ,π is required.

Technology for hadron identification

- By dE/dx measurement -> (p< 1GeV)
- TOF(time of flight) -> low particle intensity (MRPC)
- Based on Cherenkov
  - ✓ TOP(Time Of Propagation of Cherenkov count)
  - ✓ DIRC(detection of internally reflected Cherenkov light)
  - ✓ RICH(Ring imaging Cherenkov)

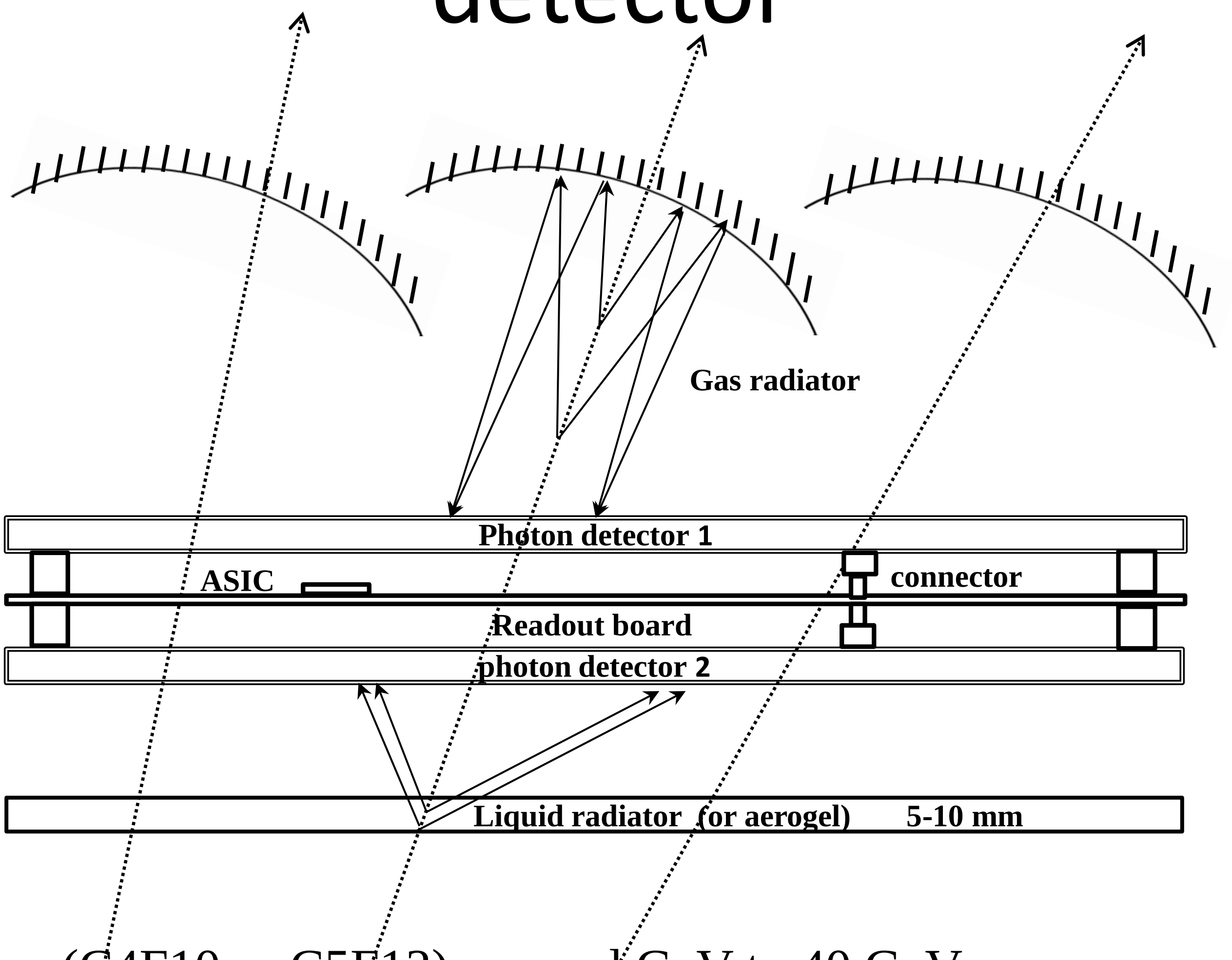
RICH detectors had been widely used,
RICH@DELPHI,
RICH1,RICH2@LHCb,
ARICH@BELLE2 etc.
And we also choose RICH as the baseline for CEPC RICH.

Advantages of RICH:

- Large dynamic range
- High rate
- Good ID capability
- Fast time response
- …

Design considerations for the RICH detector

Structure:



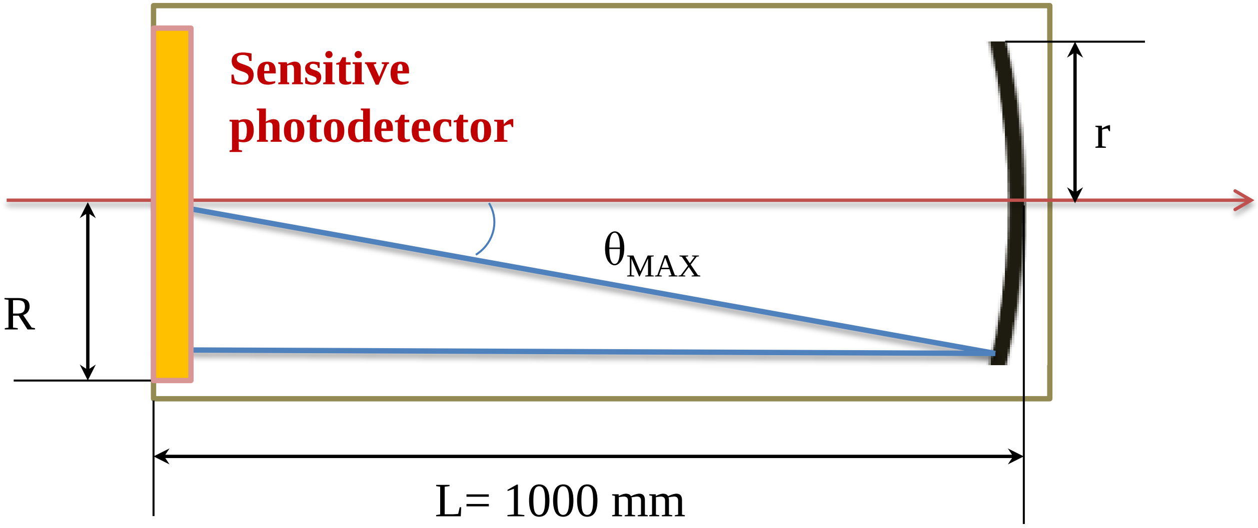
- Gas radiator (C4F10 or C5F12): several GeV to 40 GeV
- Liquid Radiator (C6F14) or Silica aerogel : sub-GeV to 10 GeV

Considerations for a prototype

A prototype is needed to validate the basic performances of designed RICH;

Requirements for 40 GeV κ,π, (C4F10 radiator):

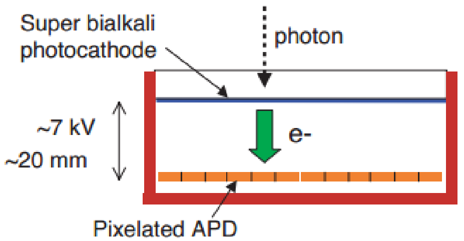
- θ_{MAX} = 0.053
- r (mirror) > L*θ_{MAX}=60 mm, R (sensitive area) = 75 mm
- Angle resolution: 2mrad



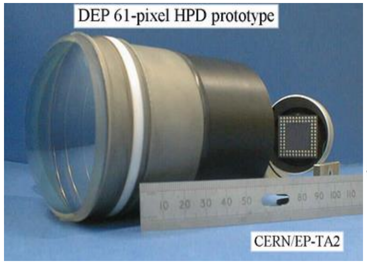
The photon detector is obviously the key challenge.

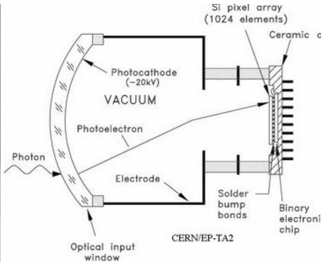
Some classical Photon detector

Hamamatsu Hybrid Avalanche PhotoDetector (HAPD) at **Belle2-ARICH**



Hybrid photon detectors (HPD at **LHCb**)





Drift Chamber based on MWPC (at **DELPHI**)

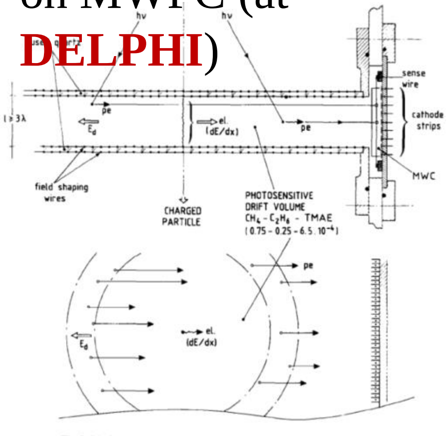
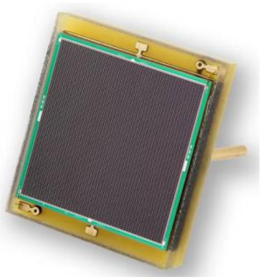
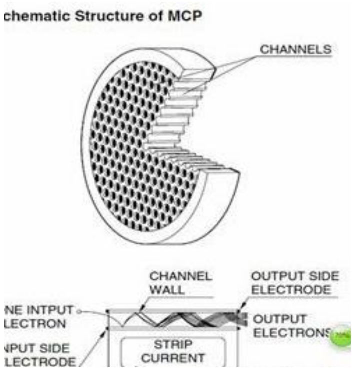


Fig. 5. Principle of a slow RICH detector using electron drift over long distances.

Some new type of Photon detectors

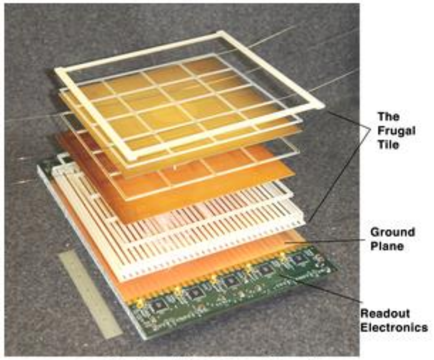
SiPM





MCP

LAPPD:
Large Area micro-channel plate photodetector



The Frugal Tile - Detector Assembly

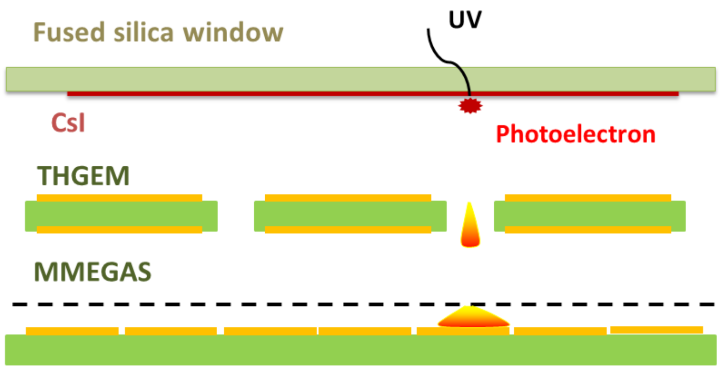
And also, MPGD (GEM, Micromegas) based Photon detector !

And MPGD (GEM, Micromegas) based Photon detector !

- COMPASS-RICH: CsI + THGEM -> THGEM + Micromegas

Advantages:

- High gas gain (>10^5)
- Fast time response
- High rate capability
- Good spatial resolution
- Low ion feedback effect
- Easy to achieve large area
- Influence-less from magnetic field



We choose the THGEM + Mmegas as the basic scheme for CEPC RICH prototype.

Comparison of RICHs using C4F10 gas radiator.

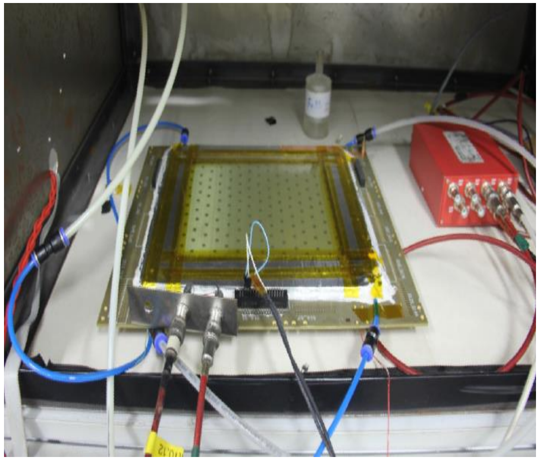
	Forward RICH of DELPHI	RICH-1 of LHCb	CEPC RICH prototype
Goals	2.5 to 25 GeV/c	10 to 65 GeV/c	20-40GeV κ,π
Active area:	Two end caps	Two end caps	15cm *15 cm
Granularity	Depend on the time resolution (~8ns) and (~5cm/μs) etc.	2.5*2.5 mm2	If 2.5*2.5mm2
Angle resolution	2.8 mrad	1.6mrad	2 mrad
Channels	26880	~200k	3600
Sensitive detector	MWPC (fast electrons signal rise time ~ns)	Silicon detector (rise time ~ 5ns)	Hybrid (THGEM+Mmegas, rise time: ~100ns)
Charge	3fC(or 30) (single photoelectron) to 1000fC (ionization)	5000e- = 8fC	$2*10^5$ e- = 30fC to ~900fC (ionization)
Event rate:	<25 KHz ?	40MHz	?
measurements	Digital time	Charge	Digital(Analog)

Micromegas R&D at USTC

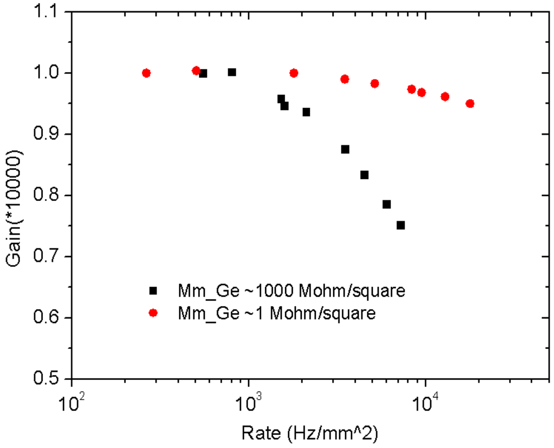
A new method which is different from “bulk” was developed to manufacture the Mmegas:

- Good performance obtained
  - ➔ Energy resolution for 5.9keV x-rays: 14.9% (FWHM) ,which is best for woven mesh Mmegas!;
  - ➔ Achieved area: 200×200 mm^2 so far;
  - ➔ High gain up to 5×10^4;
  - ➔ High rate capability up to 10^6 Hz/cm^2;
- Without etching, there is no pollution for the environment.
- Common materials and simple manufacturing processing prove a low budget …

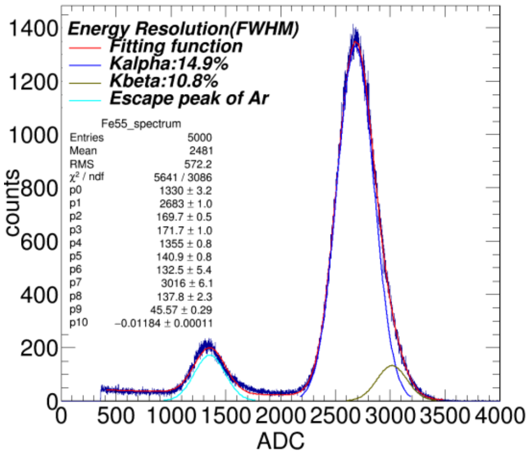
A 200×200 mm^2 prototype under testing



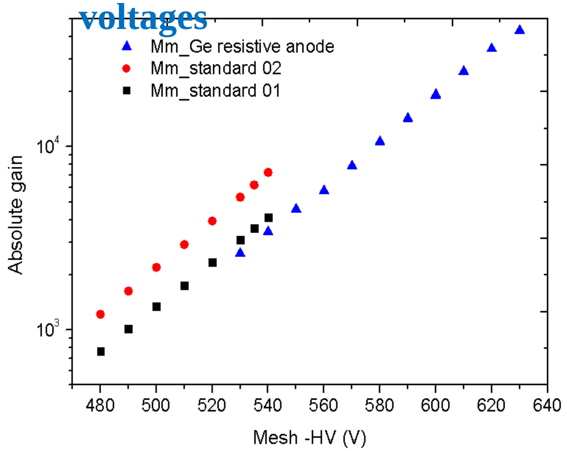
Gain vs the particle rate (8 keV Cu x-rays)



A typical ^{55}Fe x-ray spectrum

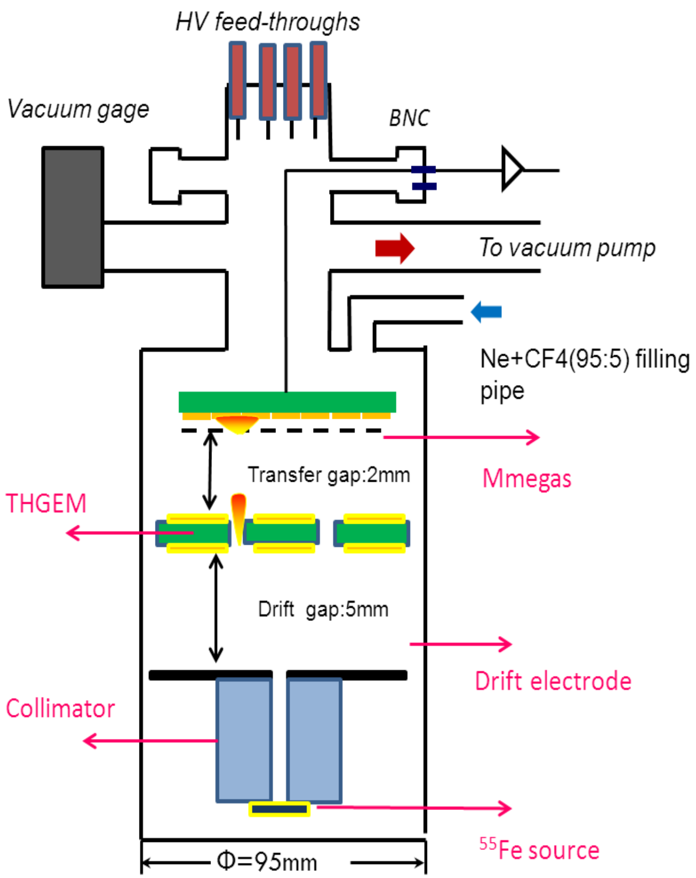


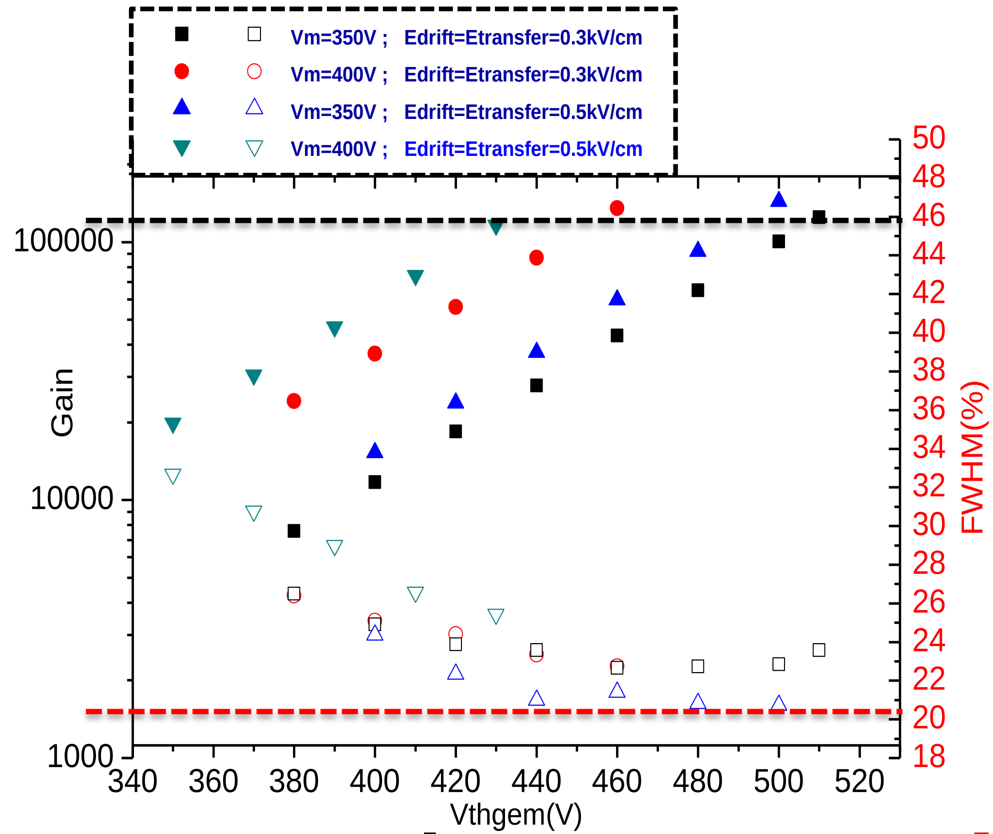
Gas gain versus mesh voltages



Test of THGEM + Mmegas hybrid structure

Gas mixture: Neon:CF4(95:5)
Source: 5.9 keV x-rays from ^{55}Fe



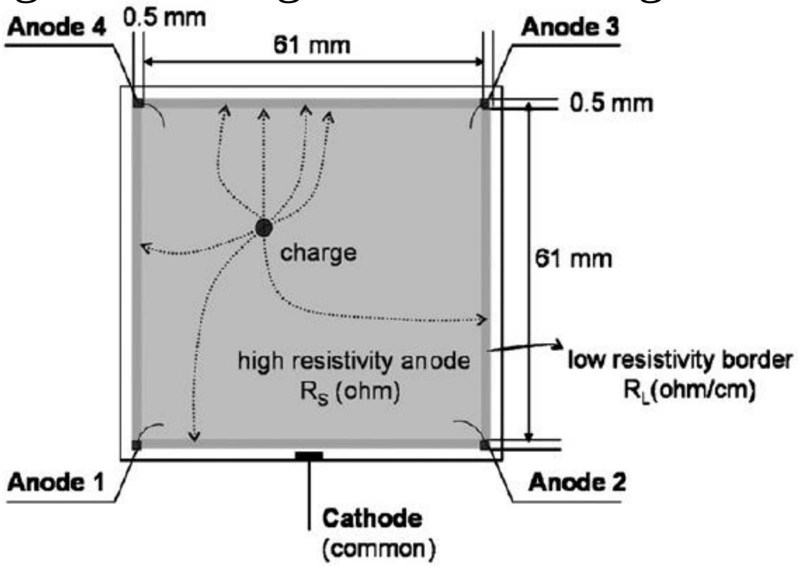


Gas gain up to 10^5, corresponding to 2×10^7 charges in the avalanche gap!
Good energy resolution ~21% (FWHM)
It will meet the requirements for single photoelectron measurement!

Try to reduce the readout channels

- A four-corner method which is used for position-sensitive silicon detectors
- (PSD) is hopeful to be used for the Mmegas readout.
- Primary simulation shows that, better than 200 um x,y spatial resolution can be obtained with 10mm × 10mm resistive-pad array anode readout!
- If it works, the number of readout channels will be cut down by 25 times!
  - 3600 to 144 channels!
- As a cost, the electronics should be changed to analog readout with a good charge linearity (~1%).

A schematic drawing of the 2D PSD. The hit position can be calculated by the distribution of charge at the four corners.



A. Banu, et al. , Nuclear Instruments and Methods in Physics Research A 593 (2008) 399–406.

Summary

- A pre-design of RICH detector for z pole measurement was proposed and CsI + (THGEM + Mmegas) hybrid structure was considered as the baseline of the photon detector.
- A prototype with gas radiators (C4F10) will be built to validate the goals of the design in 2-3 years.
- Simulation works will be carried out soon.

Thank you!

Backup slides

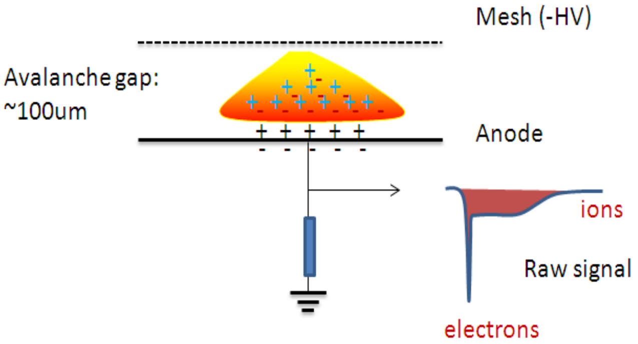
To do list

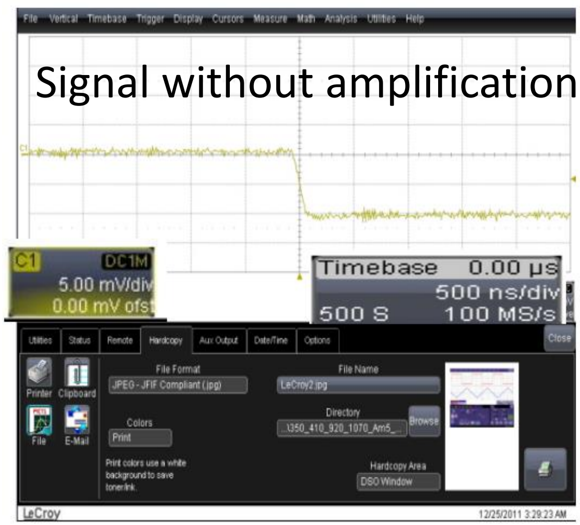
- Simulation work
  - To optimize the geometry of detector (size, materials, etc.)
  - To study the properties of the radiators (transparency, light yield, scatting, etc.), mirror (reflecting index, errors) and quartz window etc.
  - Photon detector
- Calibration and digitization for MC simulation
  - Manufacture or buy the materials mentioned and test
- Photon detector
  - The manufacture of CsI photoelectron conversion layer.
  - Fabrication and study of the THGEM and Mmegas.

Photon detector

- GEM+Micromegas
  - Granularity: 2.5 mm *2.5 mm;
  - Active area: 15cm*15cm;
  - Gas gain: $2*10^5$;

Micromegas signal





THGEM + Micromegas