MEG実験
陽電子スペクトロメータ性能改善のスタディ

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他 MEGコラボレーション

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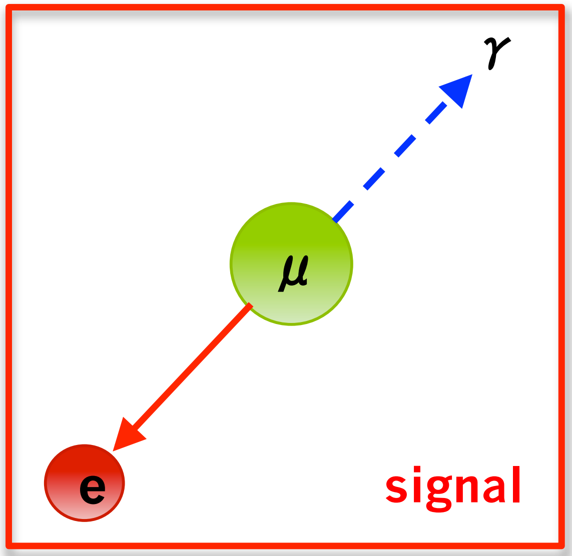
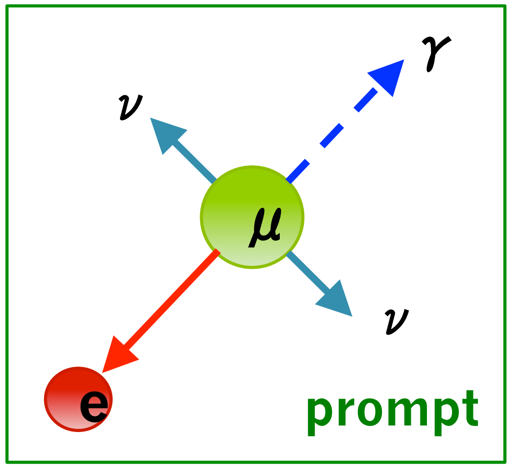
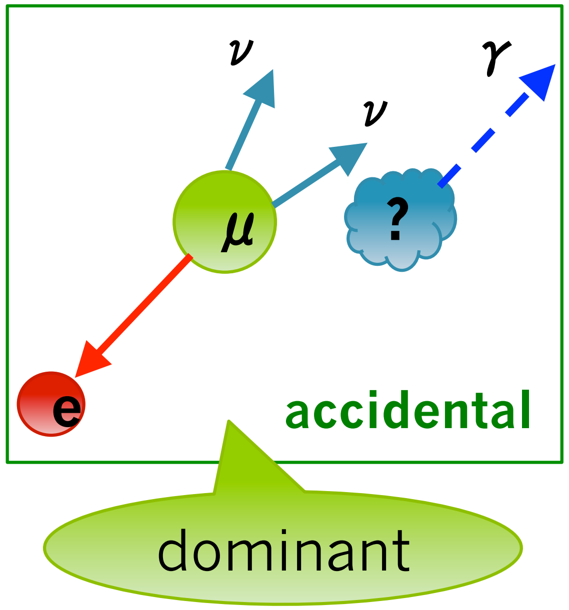
MEG experiment

- Lepton flavor violating decay, $\mu \to e\gamma$ is forbidden in the SM
  - But some of models beyond the SM predict visible $\mu \to e\gamma$ in the range of 10^{-12}-10^{-15} sensitivity
  - Current upper limit of the **B($\mu \to e\gamma$) is 2.4x10^{-12}** ,already in new physics region ! (MEG experiment, 2009+2010 data)
  - $\mu \to e\gamma$ is a good probe to search for new physics



- Background
  - Radiative muon decay (prompt)
  - Michel decay + overlapped γ (accidental)
- Experimental requirements
  - High resolution to suppress accidental background
  - High rate μ beam to get large statistics → DC muon beam @ PSI

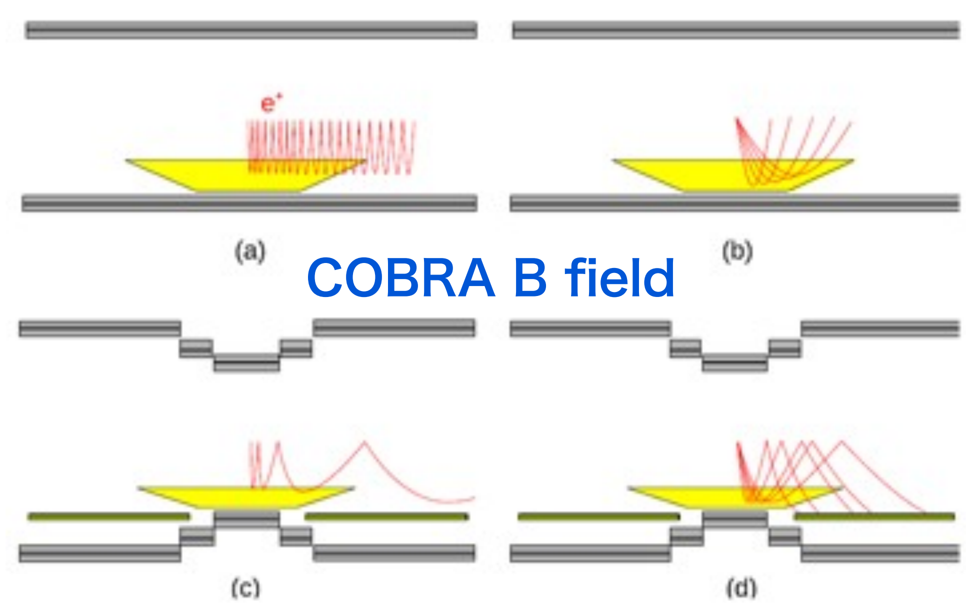


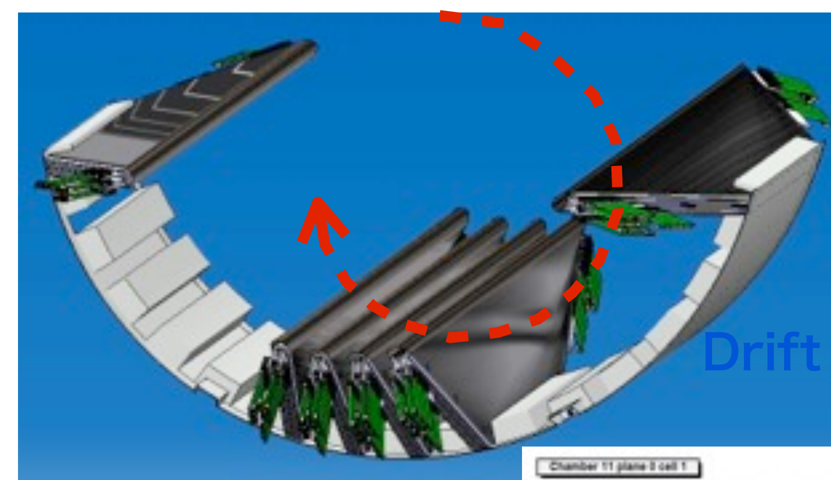


MEG experiment

- Xenon calorimeter (金子大輔 : 25pFA9)
- Positron spectrometer
  - **CO**BRA (**CO**nstant **B**ending **RA**dius) magnet
    - gradient magnetic field to be optimized for 52.8 MeV signal e+
  - **Drift chamber**
    - high resolution tracker with low mass materials
  - **Timing counter**
    - precise timing measurement for e+

Uniform B field

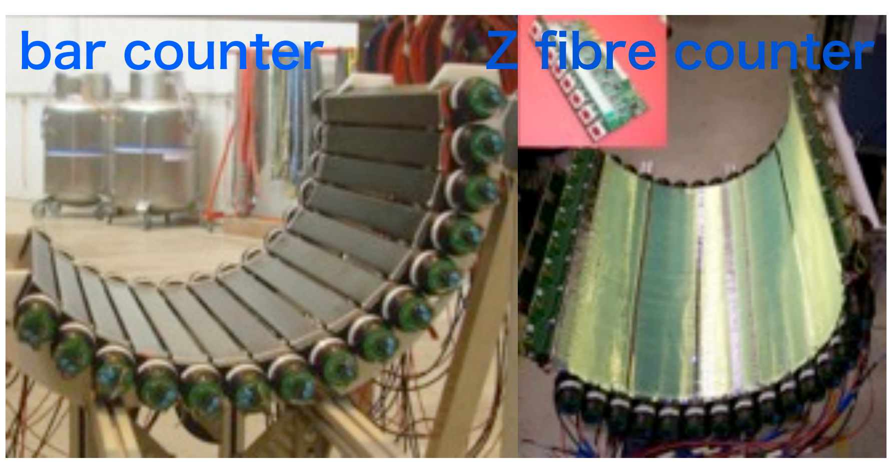


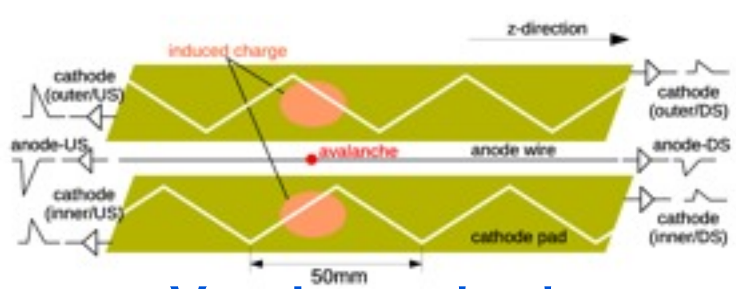


Drift chamber

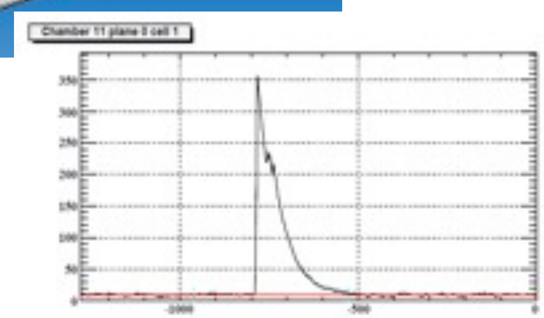
ϕ bar counter

Z fibre counter





Vernier cathode

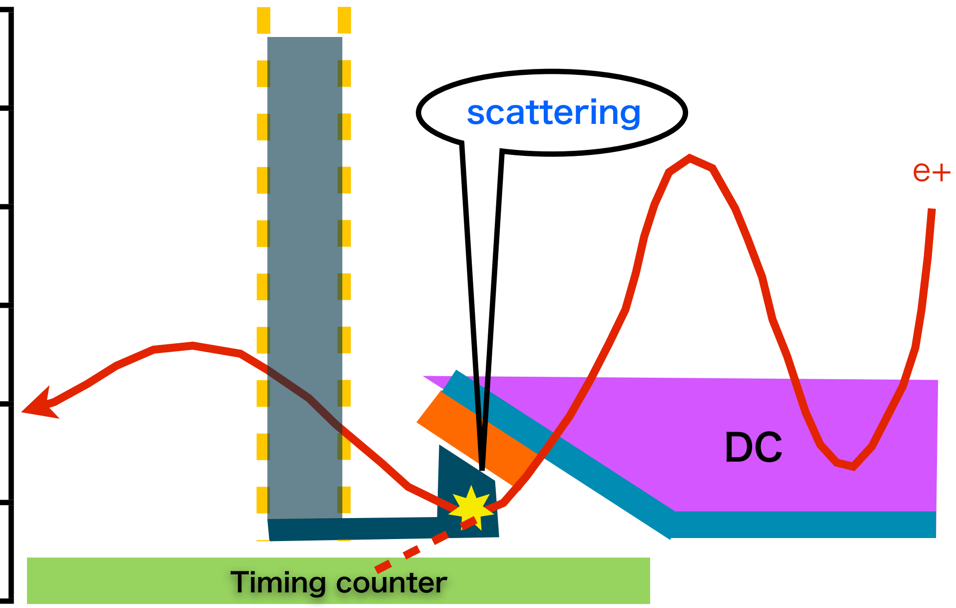


Waveform

Upgrade MEG

- Spectrometer performance
  - current performance of the positron spectrometer

	2009	2010	2011 (preliminary)
Momentum (%)	0.59 (core 80%)	0.61 (core 79%)	0.61 (core 86%)
Angle (ϕ / θ)(mrad)	6.7(core)/9.4	7.2(core)/11.0	6.5(core)/10.8
Vertex (Z/Y) (mm)	1.5/1.1	2.0/1.1	1.9/1.0
$T_{e\gamma}$ (ps)	146 (core)	126 (core)	133
ε_{e+} (%)	40	35	~40

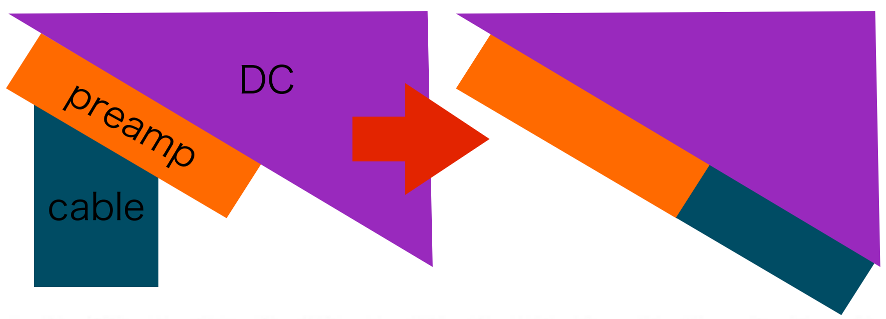


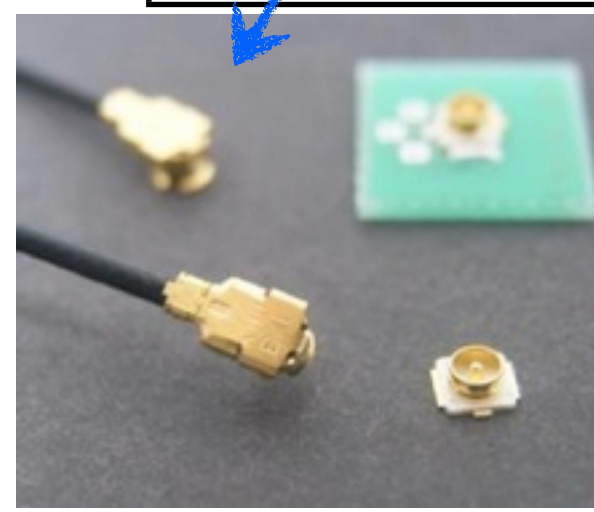
- Upgrade plan
  - MEG will finish physics data taking in a few years w/ current detectors (Goal sensitivity = 5×10^{-13})
  - We are thinking about minor upgrade during a few years data taking (**Short term upgrade**)
    - Main issue : Improve the efficiency by reducing the amount of materials between DC and TC
  - R&D for major upgrade is also started to improve the goal sensitivity ! (**Long term upgrade**)
    - Everything should be improved to get less background

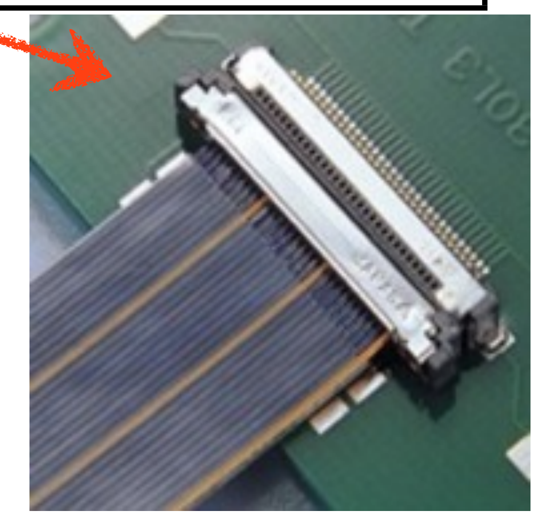
Short term upgrade

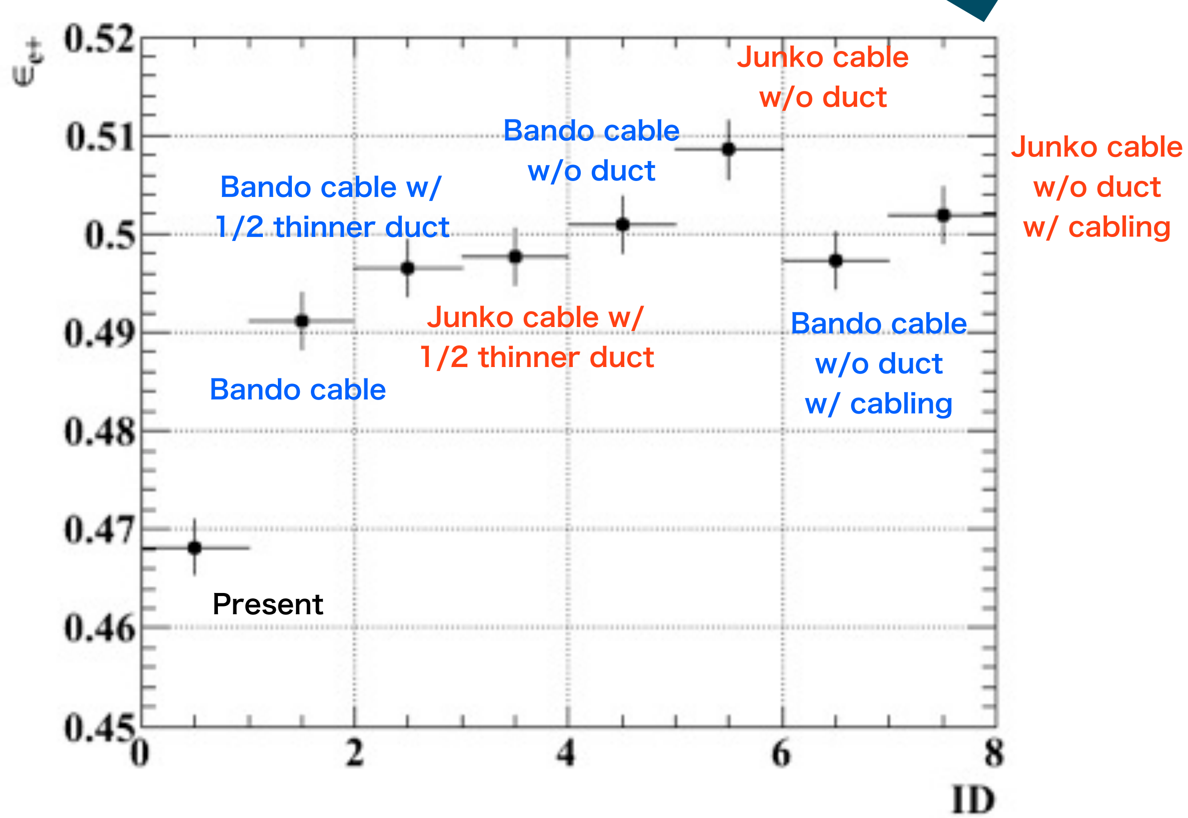
- **Short term upgrade plan**
  - Thinner cable idea
  - There are 2 candidates for new cable
  - Expected ε_{e+} improvements w/ thinner cable are evaluated w/ MC simulation based on Geant4 in some cases (2 candidates + duct modification + cabling)

	diameter (mm)
Radiall (present)	1.8
Bando	0.8
Junko	0.34





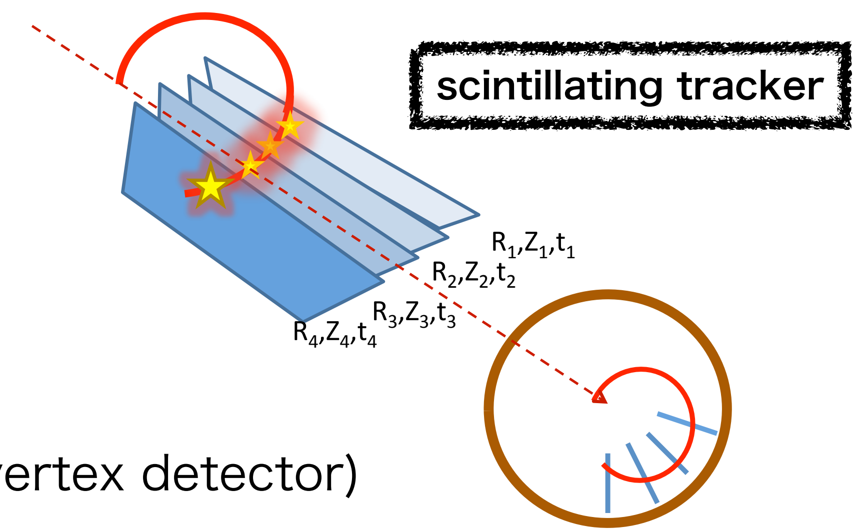




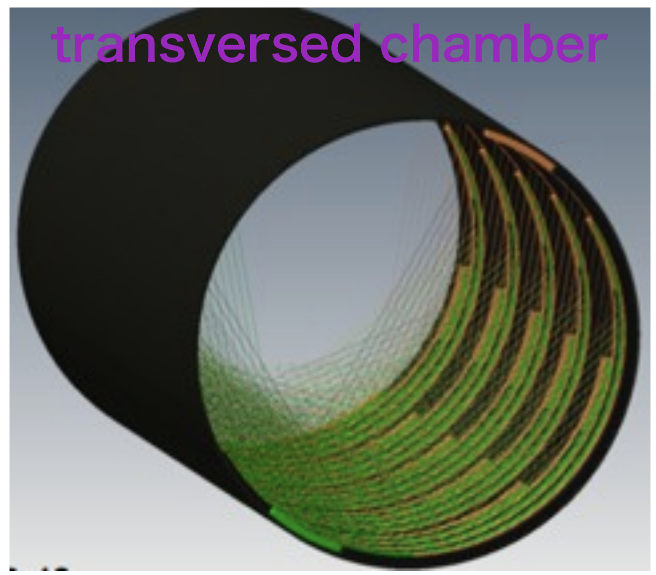
- **Summary**
  - ε_{e+} can be improved in **5-9** % relatively by replacing cable and modifying cable duct
  - Cabling also affect the efficiency → should be optimized
  - The effect of signal attenuation w/ thinner cable is not yet evaluated → waveform simulation is needed

Long term upgrade

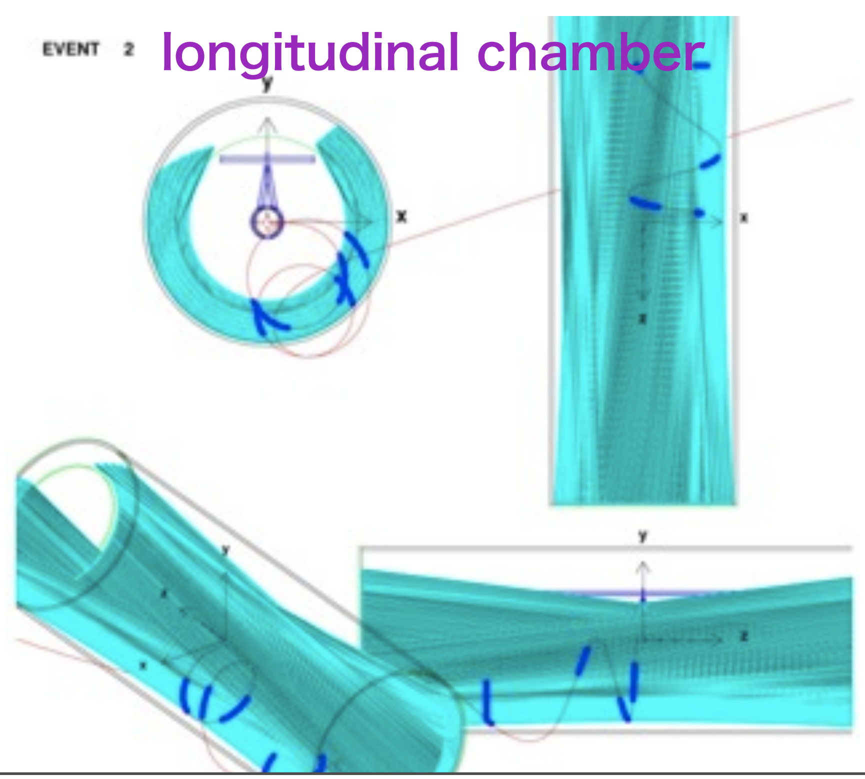
- We are also thinking major upgrade (澤田龍 : 25pFA10)
  - Beam (muon rate : $3\times10^7 \rightarrow$ **1×10^8** already available @ beamline)
  - Target
  - Xenon calorimeter
  - Positron spectrometer
  - Additional detectors ? (e. g. Si vertex detector)



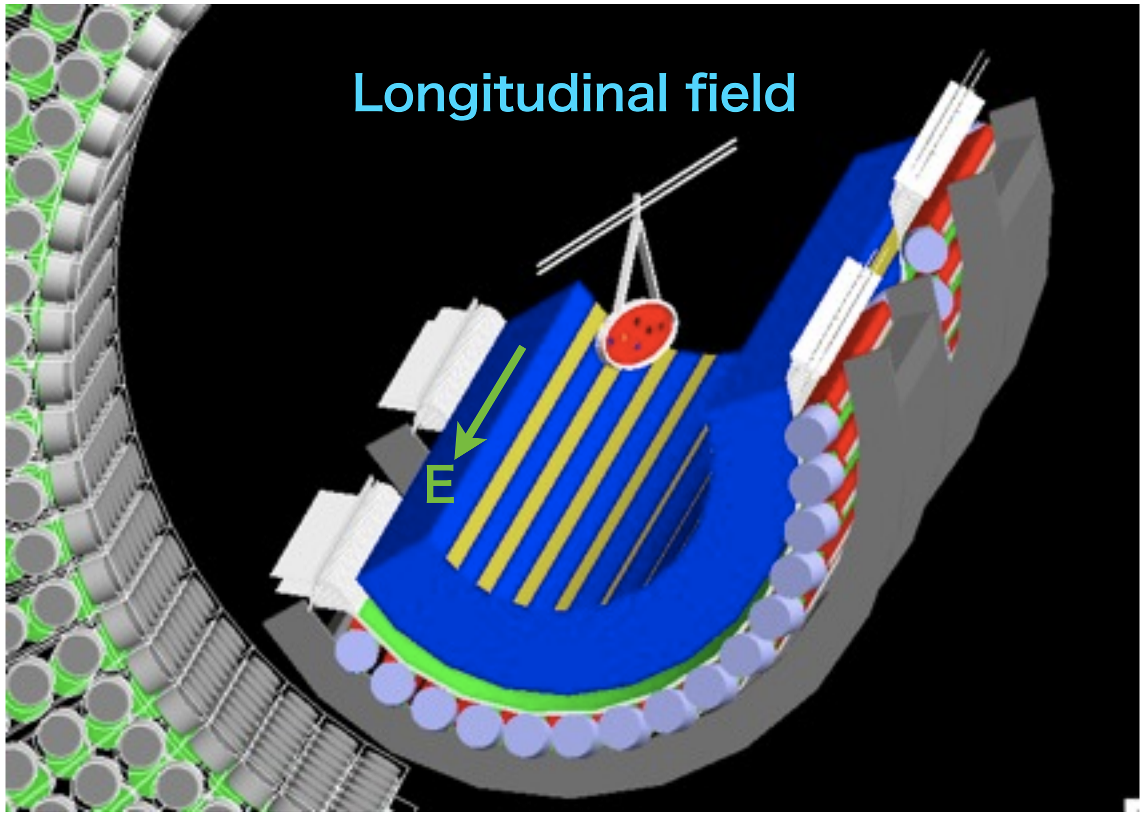
stereo wire chamber

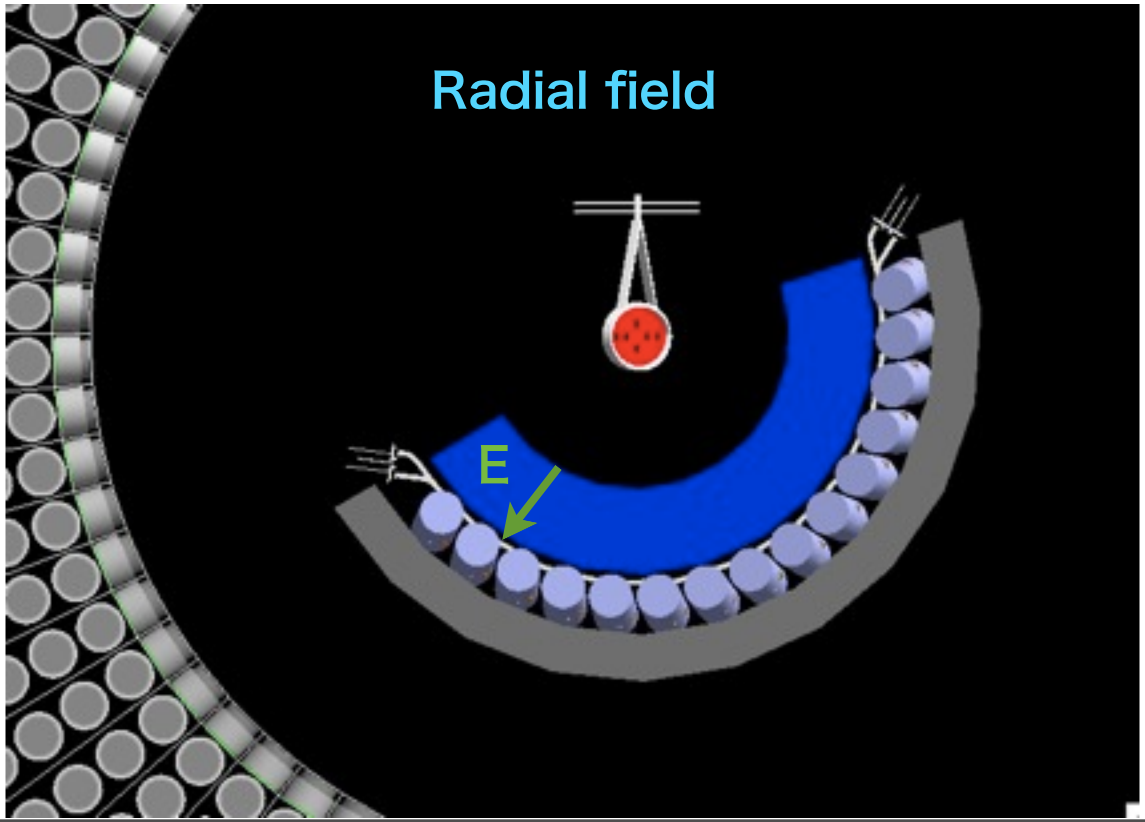


- To get less background, everything should be improved
  - 2 times higher efficiency
  - 2 times better resolutions
  - Stable operation under 3 times higher muon rate
- New tracker is needed to achieve this goal !
  - Can we use TPC as one of the candidate for new tracker ?



TPC concept





- **TPC is good for our aiming**
  - Good spacial resolution with light materials (Helium base)
- **Single volume, wider coverage region**
  - Much more # of measurement points (×10)
  - Good for higher efficiency
- **Longitudinal field**
  - Very popular and a lot of experience in other groups (e. g. ILC, ALICE, LHCb, , ...)
  - Longer drift distance (Max ~100 cm)
- **Radial field**
  - Shorter drift distance (Max ~ 10 cm)
  - Only a several experiments (will) use radial design (NA49, BoNuS)

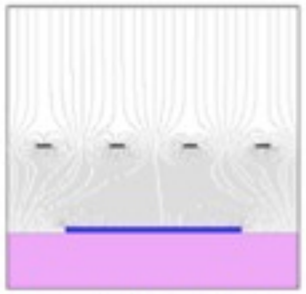
Gas

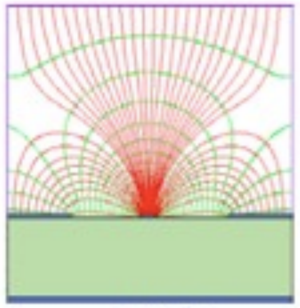
- ## Gas mixture
  - Some gas mixtures are simulated with `Garfield`

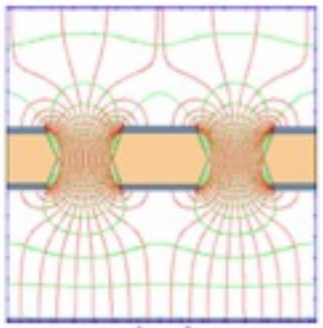
@ 1kV	Radiation Length	D_T um/√cm	D_L um/√cm	v_D cm/us	Np /cm
He:CO2=70:30	0.09% X0	120	130	1.9	15
He:C2H6=70:30	0.07% X0	215	146	2.9	22
He:C2H6=50:50	0.10% X0	195	133	3.5	45

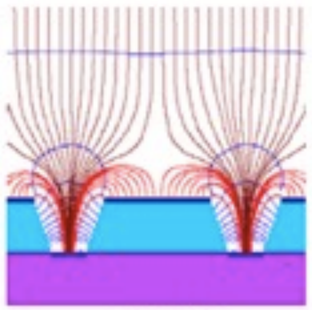
  - Each case also have weak point & strong point

- ## Gas gain
  - Apply existing technology
    - Still under discussion


parallel plate


strip


hole

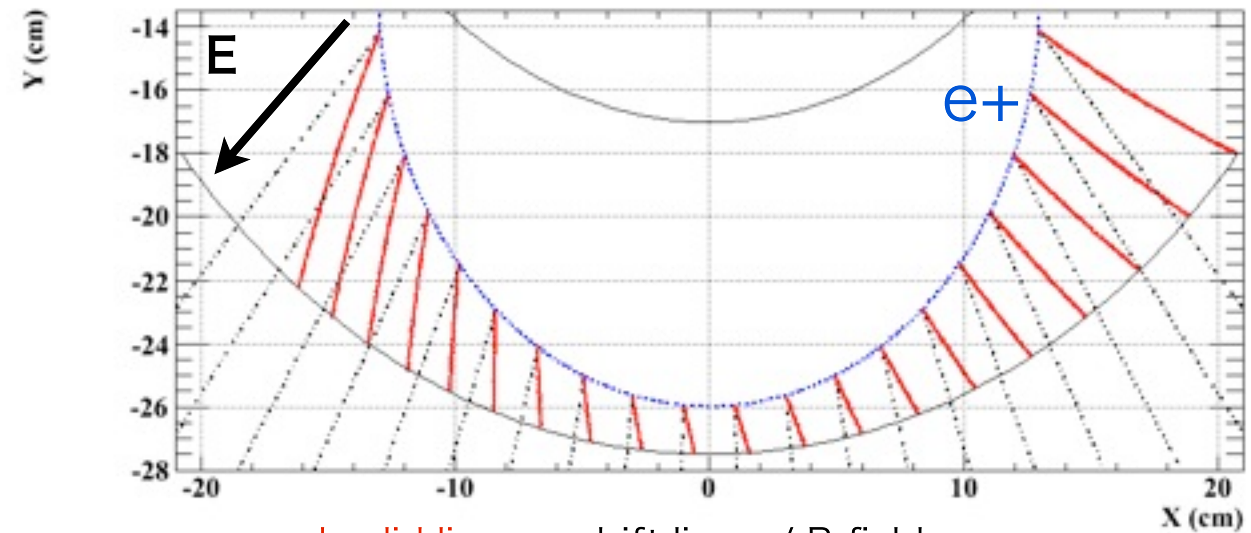

groove

B field effect

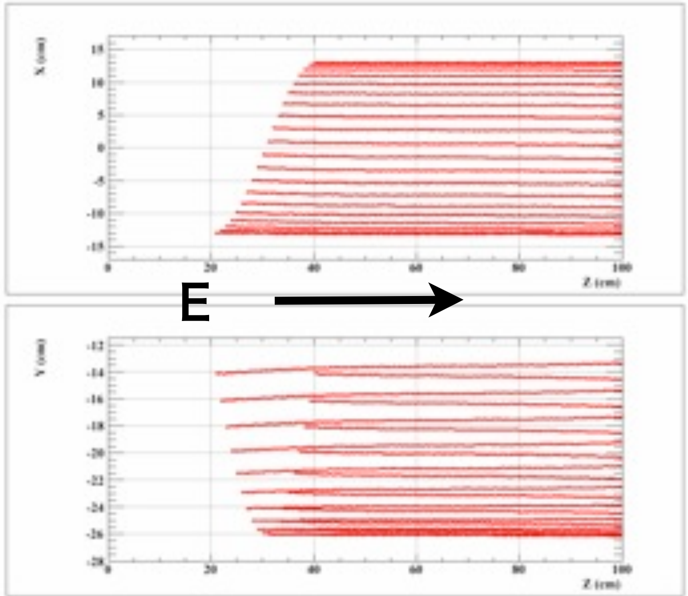
- **Magnetic field effect**
  - Drift line of ionized electron must be distorte by the COBRA magnetic field
  - B-field uncertainty is lower than 0.2%
  - Check how affect the B-field and its uncertai in analytic way
  - Drift formula w/ magnetic field is defined below

$$\mathbf{u} = \frac{eE\tau/m}{1+(\omega\tau)^2}\left[\hat{\mathbf{E}} + \omega\tau(\hat{\mathbf{E}}\times\hat{\mathbf{B}}) + (\omega\tau)^2(\hat{\mathbf{E}}\cdot\hat{\mathbf{B}})\hat{\mathbf{B}}\right]$$

  - Shift the field alignment in 1mm or scale the field strength in 0.2 %
  - Compare position and drift time difference between original field and modified field ...
  -



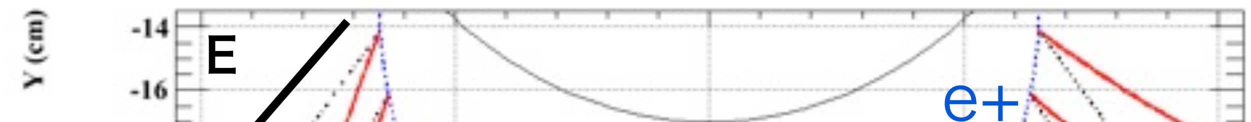
red solid line : e- drift line w/ B-field
black dotted line : drift line w/o B-field
E = 1kV/cm @ z = 0



red solid line : e- drift line
E = 1 kV/cm

B field effect

- **Magnetic field effect**



	Radial/Long. shift in X	Radial/Long. shift in Y	Radial/Long. shift in Z	Radial/Long. scale 0.2%
RMS x (um)	4.1 / 19	1.7 / 17	2.7 / 15	5.3 / 5.6
RMS y (um)	3.2 / 18	2.1 / 15	1.7 / 13	3.8 / 21
RMS z (um)	12 / 13	5.4 / 26	7.0 / 33	13 / 29
RMS t (ns)	0.2 / 2.7	<0.1 / 1.9	0.2 / 2.1	0.3 / 3.8

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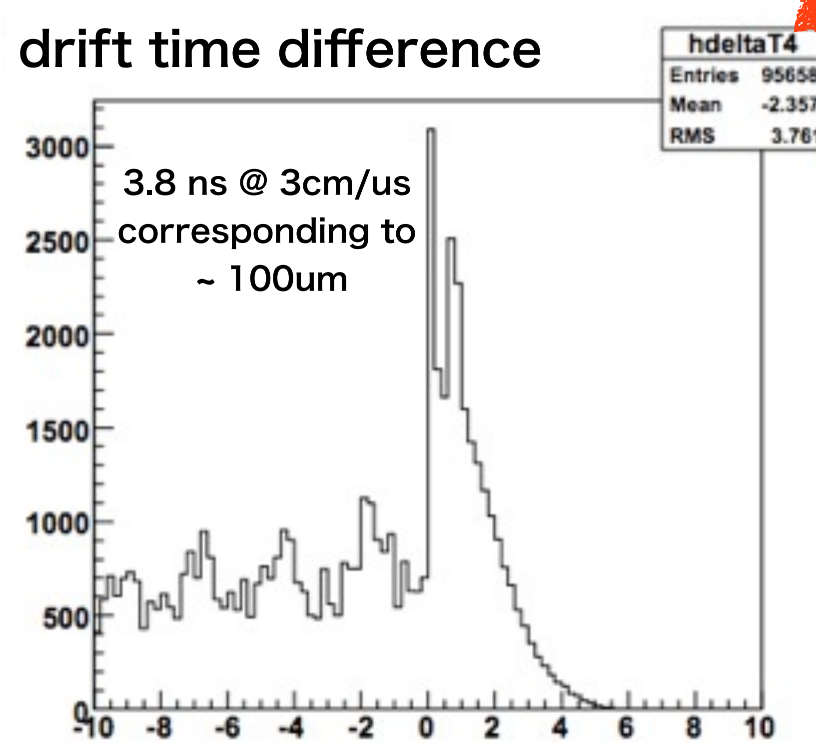
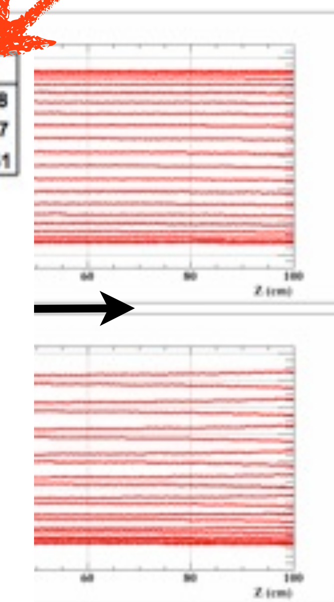
$$\mathbf{u} = \frac{eE\tau/m}{1+(\omega\tau)^2}\left[\hat{\mathbf{E}} + \omega\tau(\hat{\mathbf{E}}\times\hat{\mathbf{B}}) + (\omega\tau)^2(\hat{\mathbf{E}}\cdot\hat{\mathbf{B}})\hat{\mathbf{B}}\right]$$

- Shift the field alignment in 1mm or scale the field strength in 0.2 %

- Compare position and drift time difference between original field and modified field ...

- Radial case is much better than Long. case !





drift line

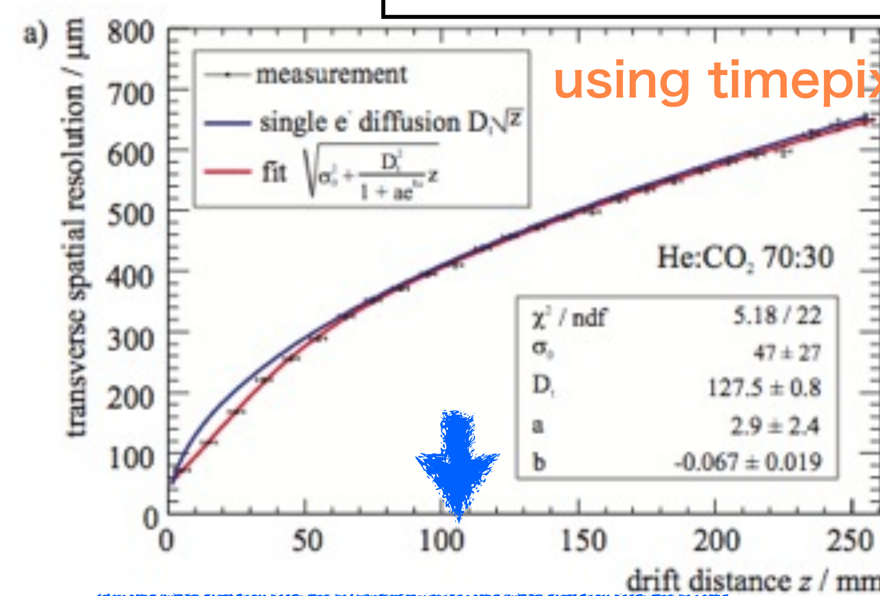
Expected performance

- **Spatial resolution**
  - δR : ~ 200 um (achievable if δt < 5 ns)
  - $\delta (z\text{-}\phi)$: ~ 500 um
- **Momentum**
  - very laugh estimation by assuming uniform B field
  - $\delta p = \sqrt{((\delta p_{Fit})^2 + (\delta p_{MAG})^2 + (\delta p_{MS})^2)}$
  - 350 keV (DC) → **180 keV** (TPC)
- **Efficiency**
  - Evaluated with Geant 4
  - 50 um thin mylar wall + 1 um cathode copper + He:CO2(70:30) + 3 gems (50um Kapton between 5 um copper) + 5um copper readout pad
  - 40 % (DC) → **80 - 90 %** (TPC)

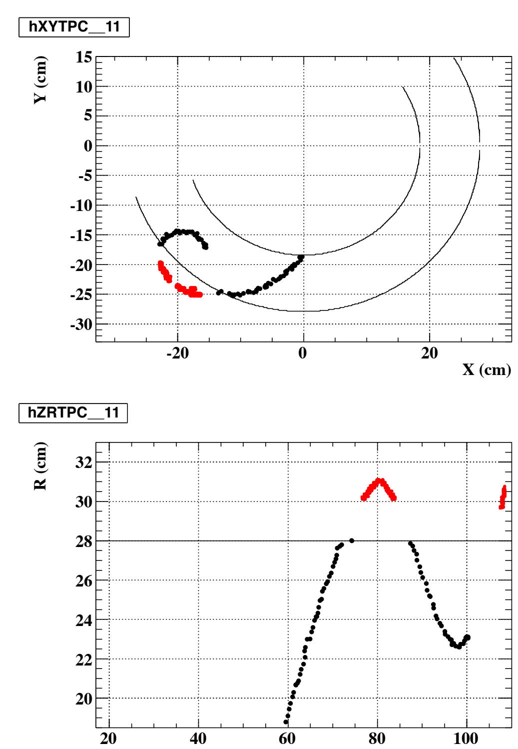
~ 50 keV ?

~ 120 keV

2009 JINST 4 P11015



$$\delta k_{res} = \frac{\epsilon}{L'^2}\sqrt{\frac{720}{N+4}},$$

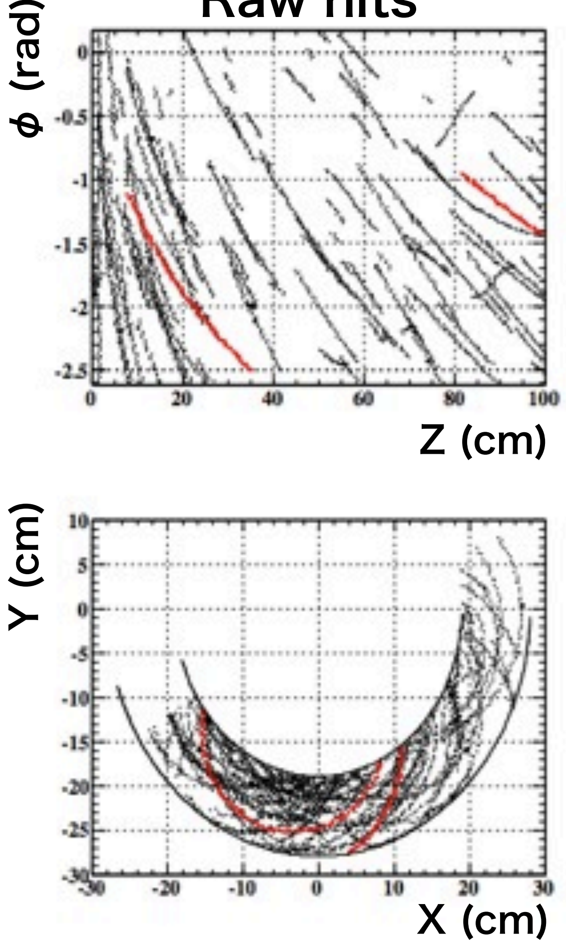


- : true hits in TPC
- : true hits in TC

Expected performance

- **Multiplicity**
  - How many hits in one trigger ? In the analysis or hardware point of view, Are they acceptable ?
  - Ionized electron travel about 10 cm in drift velocity ~ 3 cm/us
  - At least 3 us time window is needed to collect ionized electron generated at the farthest position

Raw hits



← How to reduce ?

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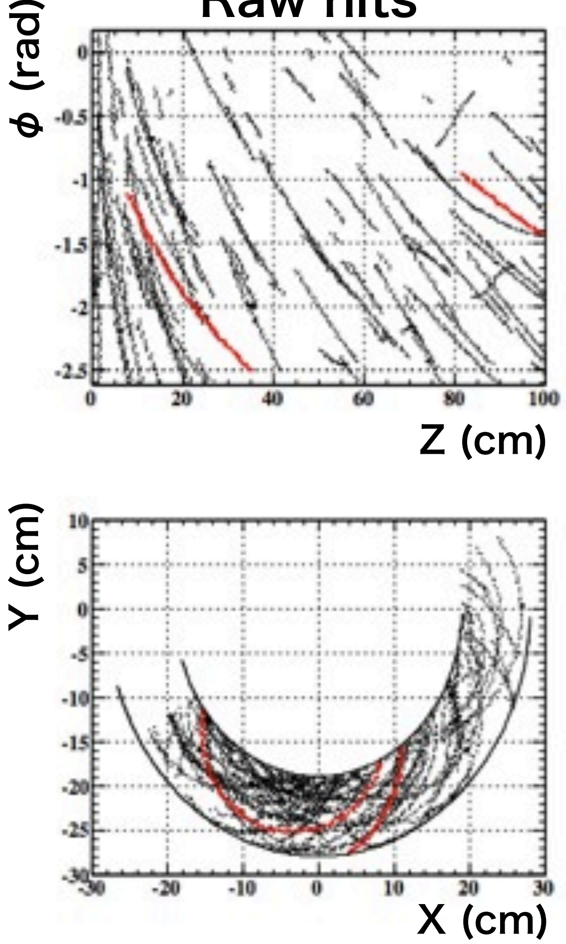
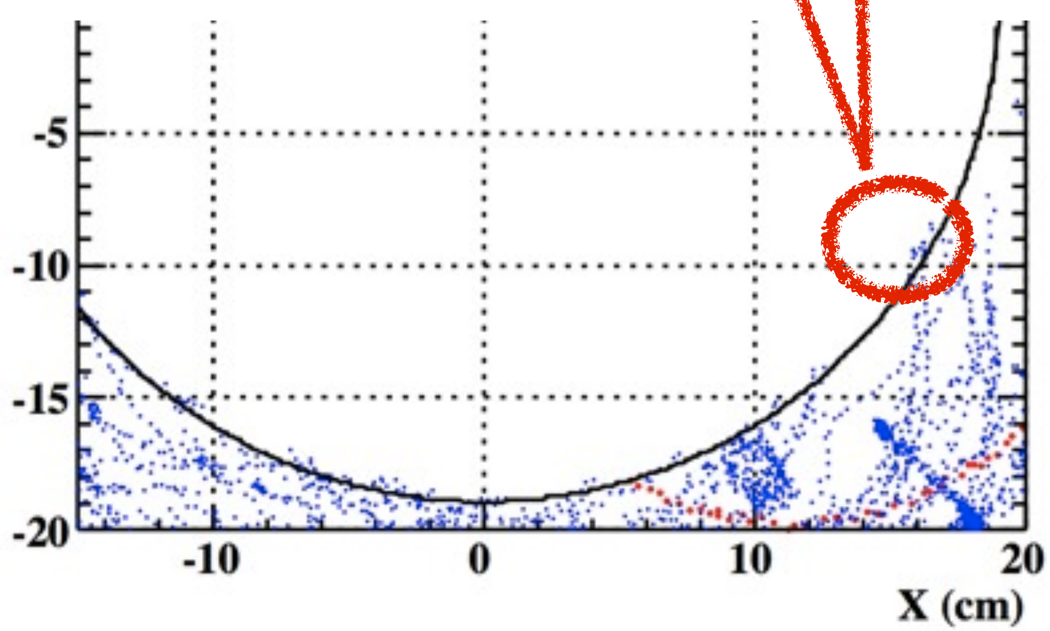
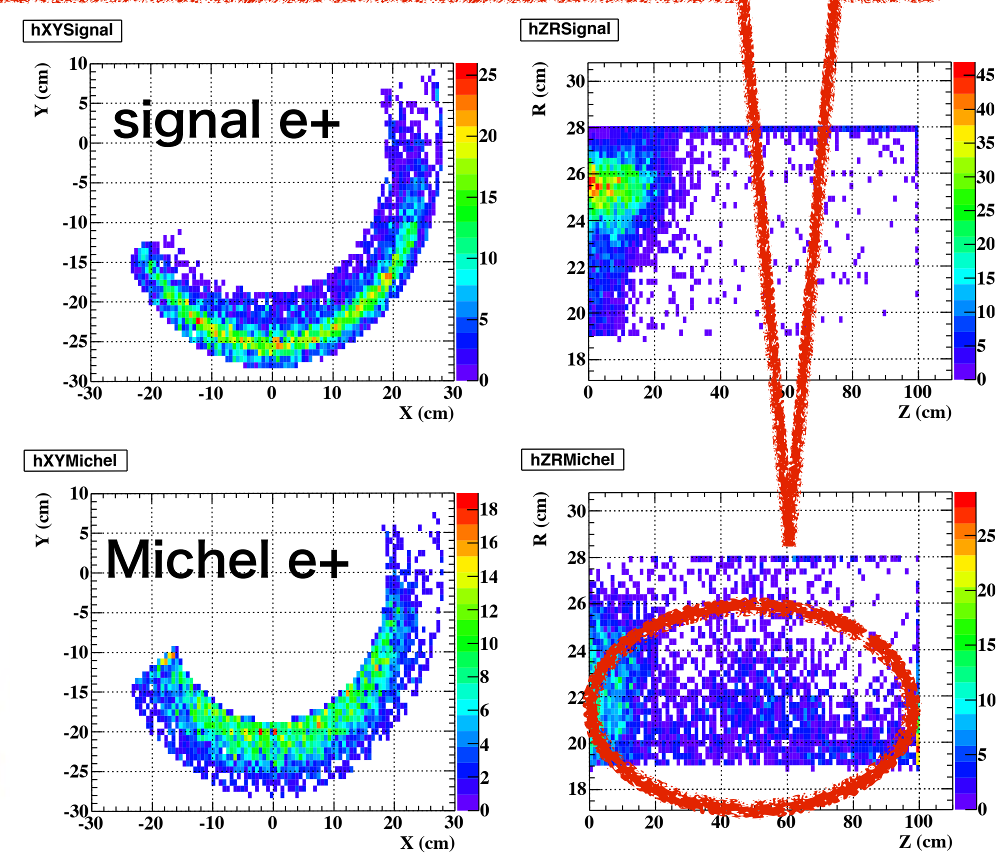


if track timing is not related to the trigger,
minimum R position of track is not on TPC wall plane



if momentum of track is low and not enter the TC,
maximum R position of track is smaller than it of signal



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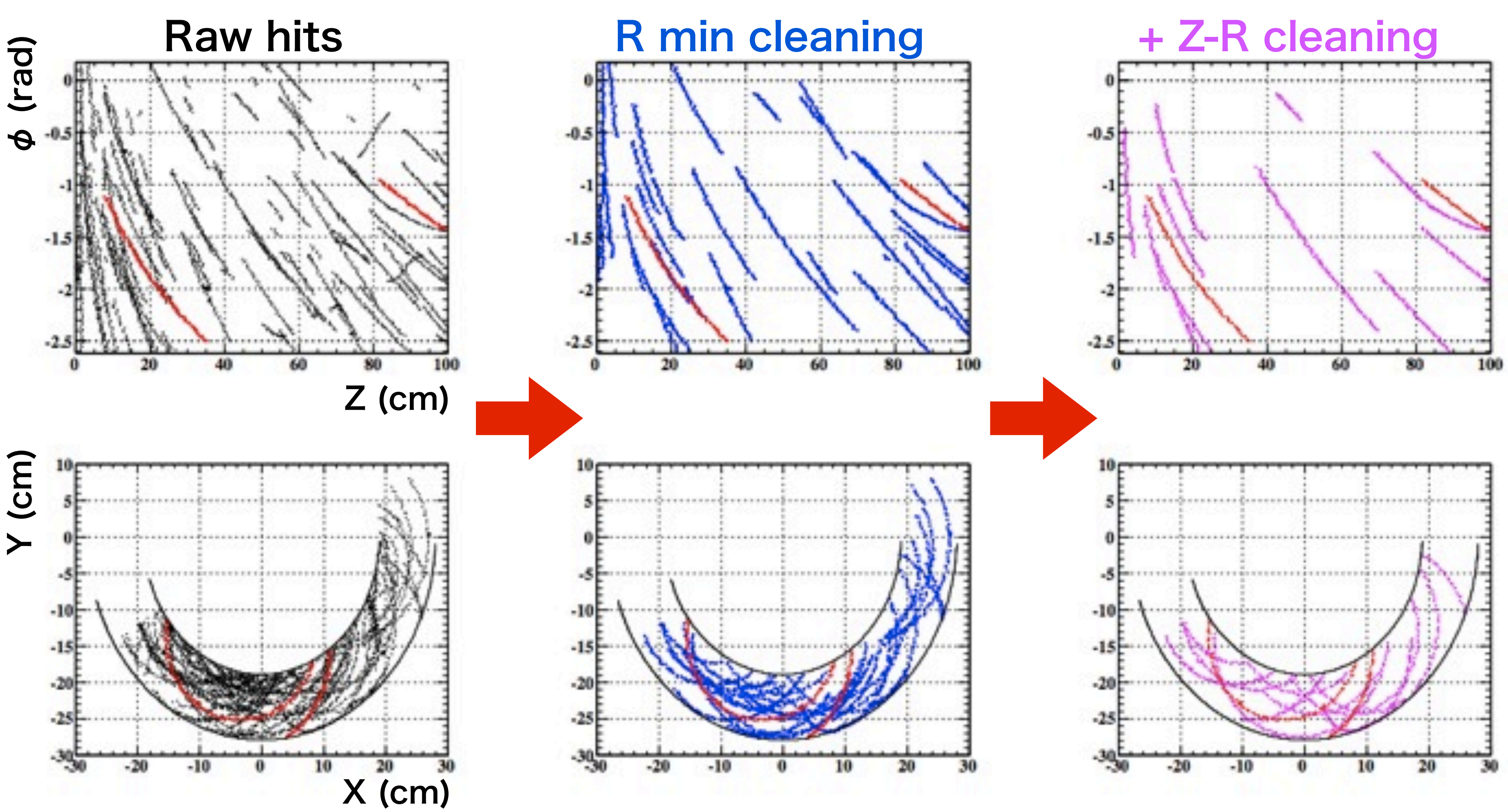


(#of signal hits)/(#of total hits)

0.058

↓

0.117

↓

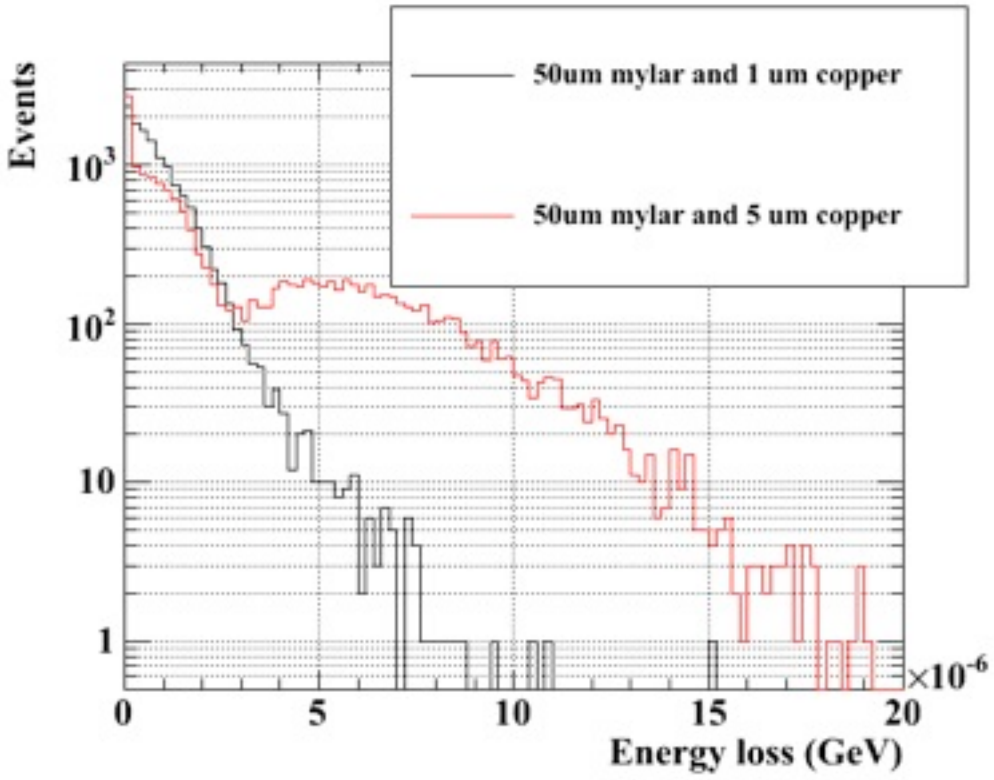
0.201

Summary

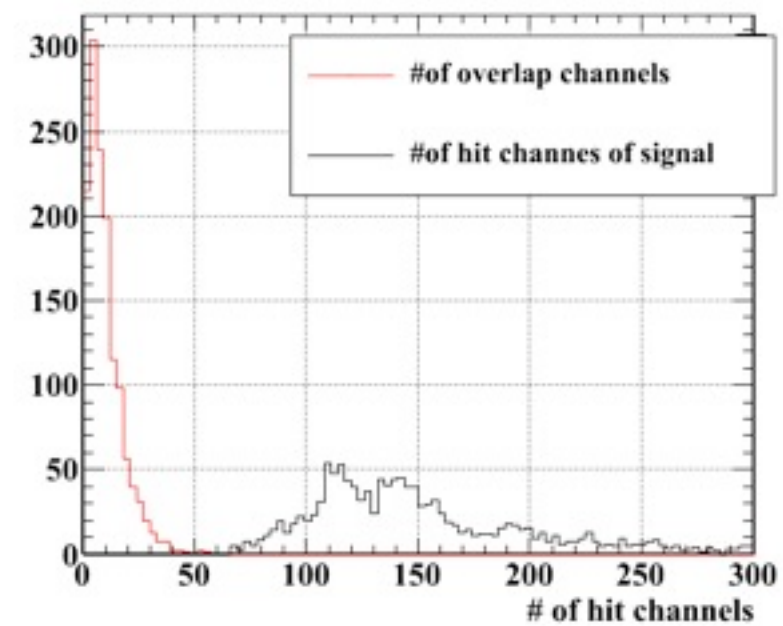
- **Summary of TPC idea**
  - We are planning “**MEG upgrade**” to get better sensitivity
  - The study of Helium based TPC started as one of candidate for our new tracker
  - Radial type field is less affected by uncertainty of magnetic field
  - Twice better efficiency & twice better momentum resolution are expected roughly
    - δp : 350 keV → 180 keV
    - ε_{e+} : 40 % → 80 - 90 %
  - More realistic estimation (w/ reconstruction) is needed
  - R&D with prototype is necessary
  - There are still a lot of things to be discussed
    - Gas gain
    - Readout
    - Support structure
  - **Any cooperates or suggestions are welcome !**

Backup

- energy loss @ inner TPC wall with copper cathode
  - case 1 : 50 um Mylar + 1 um Copper
  - case 2 : 50 um Mylar + 5 um Copper
- Calculate energy deposits in above 2 case in Geant4
  - case 1 looks fine



- Pileup probability
  - Some channels have pile up hits in time width of 1 trigger
  - I calculated this effect by mixing 1 triggered signal event and overlapping Michel event assuming 1×10^{8} stopping muon rate
  - Readout pad is divided by 2.5x5 mm2 in Z-ϕ plane (typical value for Multi layers gem)
  - results
  - pileup probability : (#of pileup hits)/(#of signal hits) ~ 6 %
  - If we can divide each hits in 30 nsec accuracy, it can be reduced to 1/100



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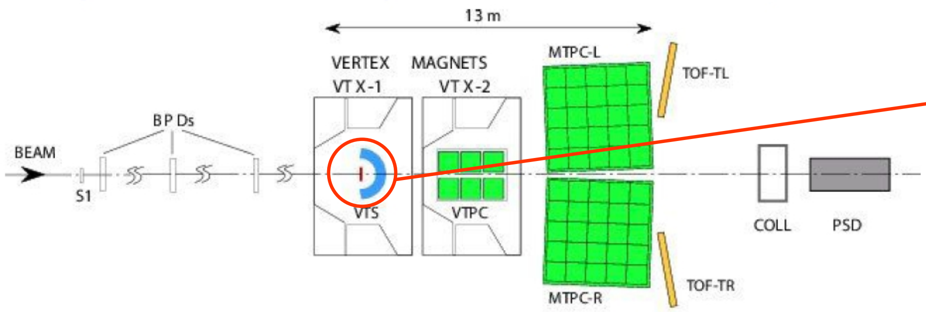
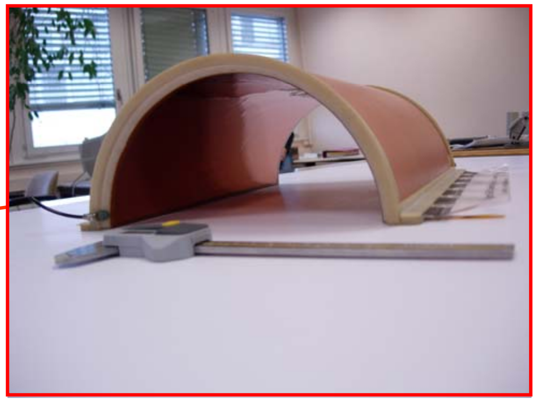
Cylindrical GEM for NA49-Future

GEM at CERN
Leszek Ropelewski CERN PH-DT2-ST & TOTEM

A possible "critical" experiment at the CERN SPS





-a precise determination of an event centrality (**PSD**)

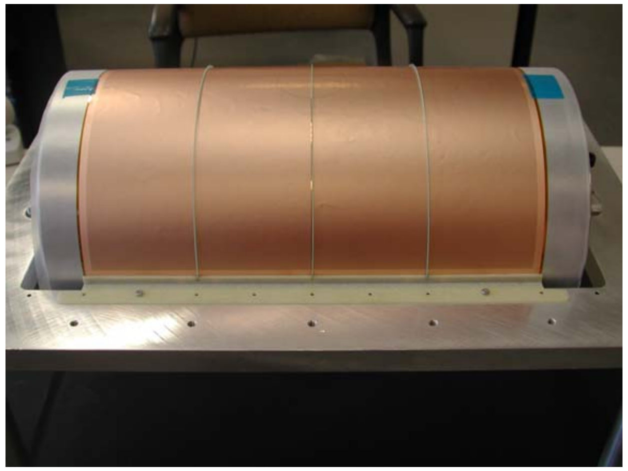
-full acceptance for charged hadrons (**VTS**)
and limited for identified hadrons (**TPCs**)

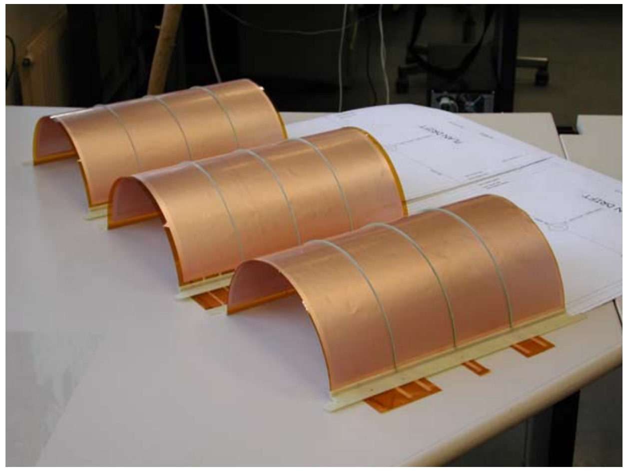
-a high event rate (**DAQ**)

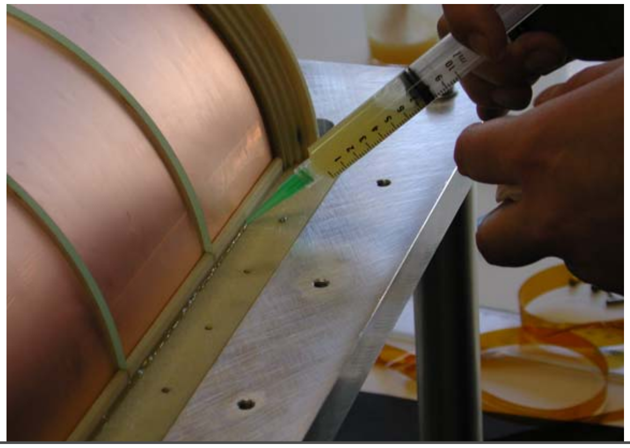
-high precision measurements of inclusive spectra
of identified hadrons (**TPCs+TOF**)

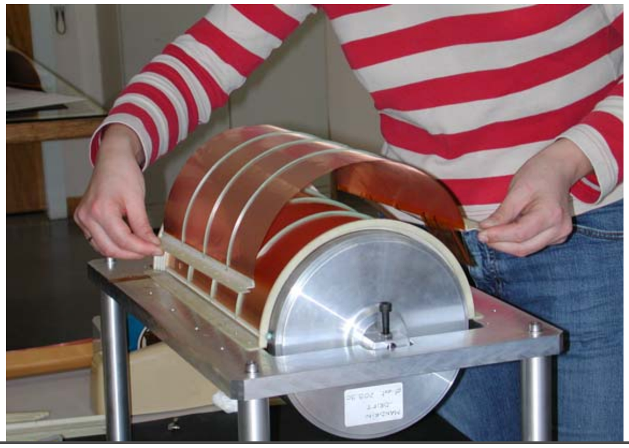
Cylindrical GEM Assembly 2

GEM foils









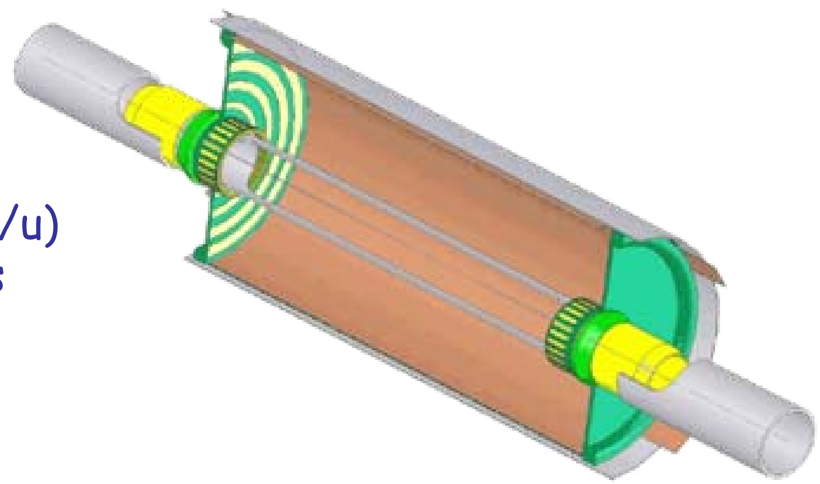
TACTIC and BoNuS

TRIUMF Annular Chamber for Tracking and Identification of Charged particles

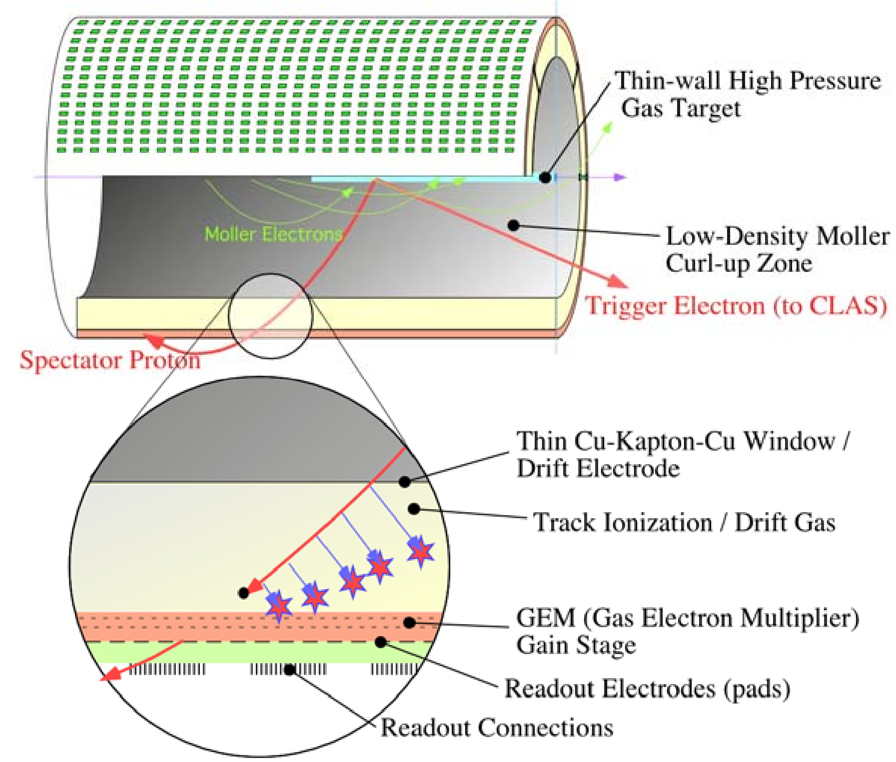
Measurement of nuclear cross sections for astrophysics

^{8}Li(α,n) ^{11}B

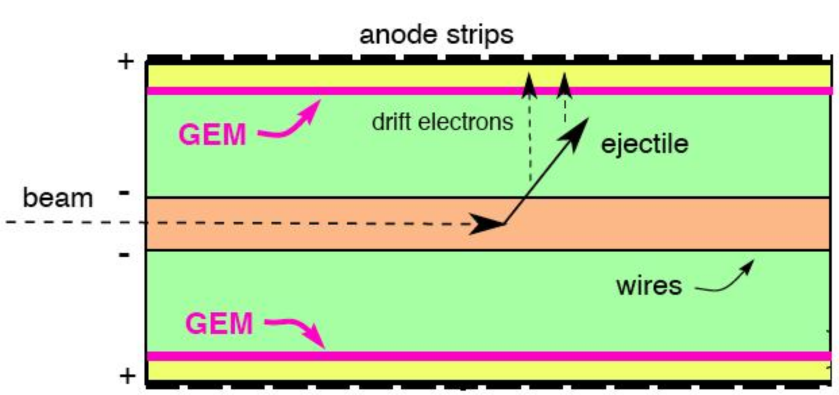
^{8}Li ions (90-220 keV/u) interacting in He gas

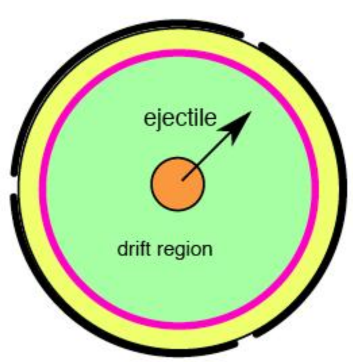


BoNuS Radial Time Projection Chamber in JLAB

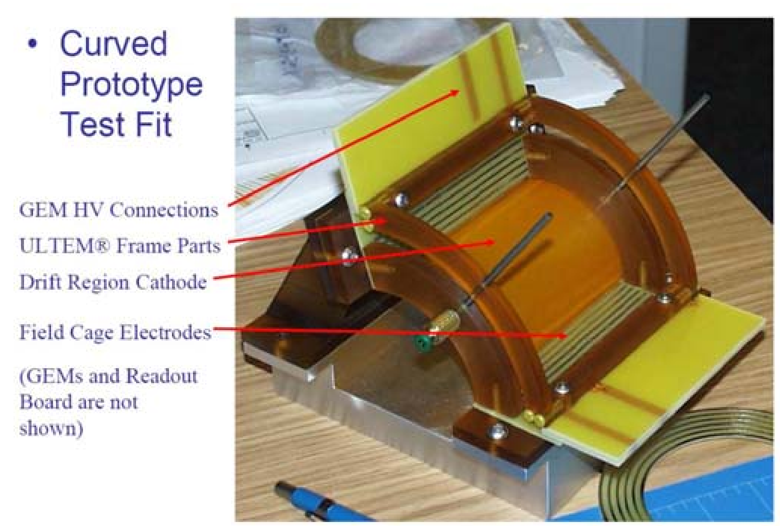


Cylindrical GEM detector with pad readout:



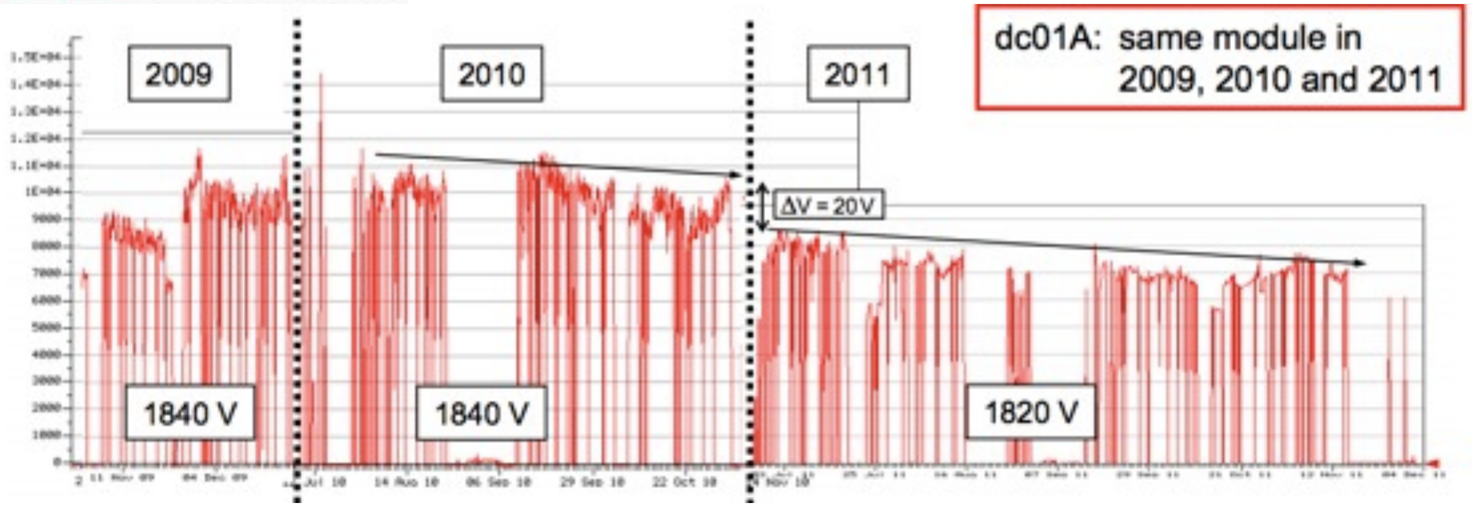


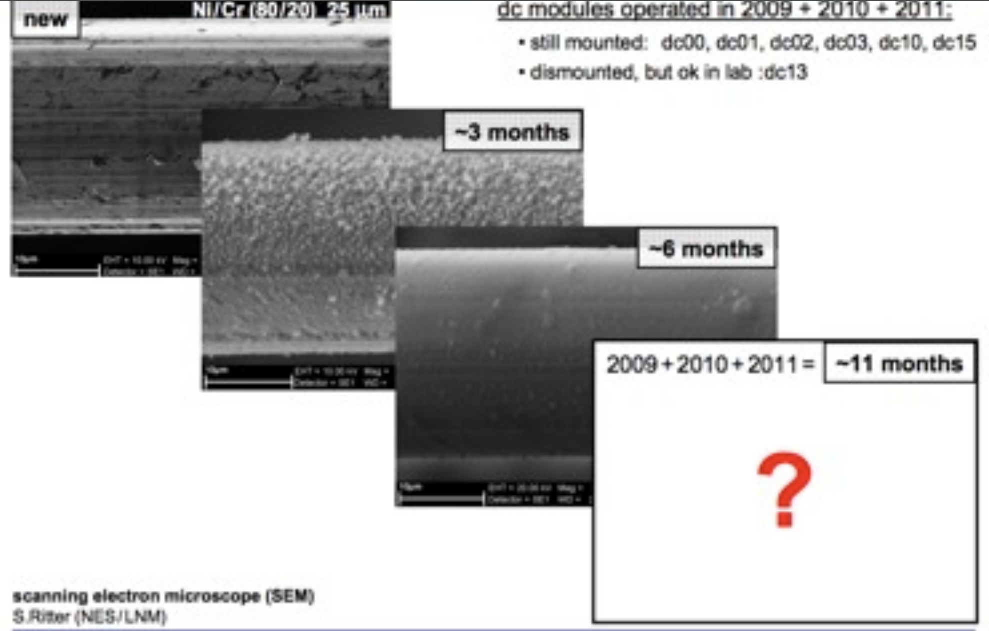
- Curved Prototype Test Fit



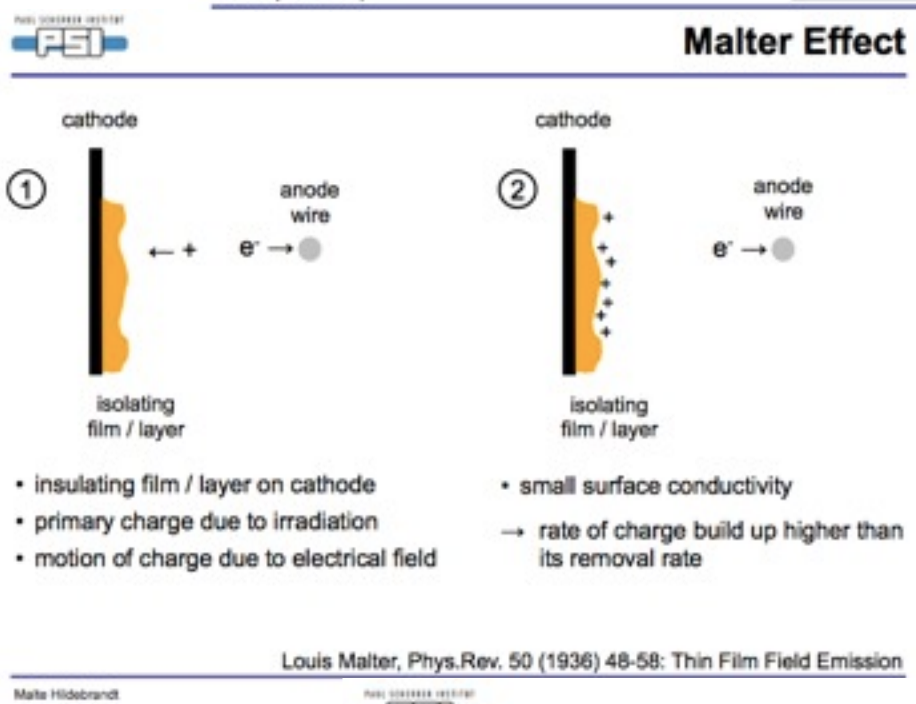
http://tactic.triumf.ca/about.html

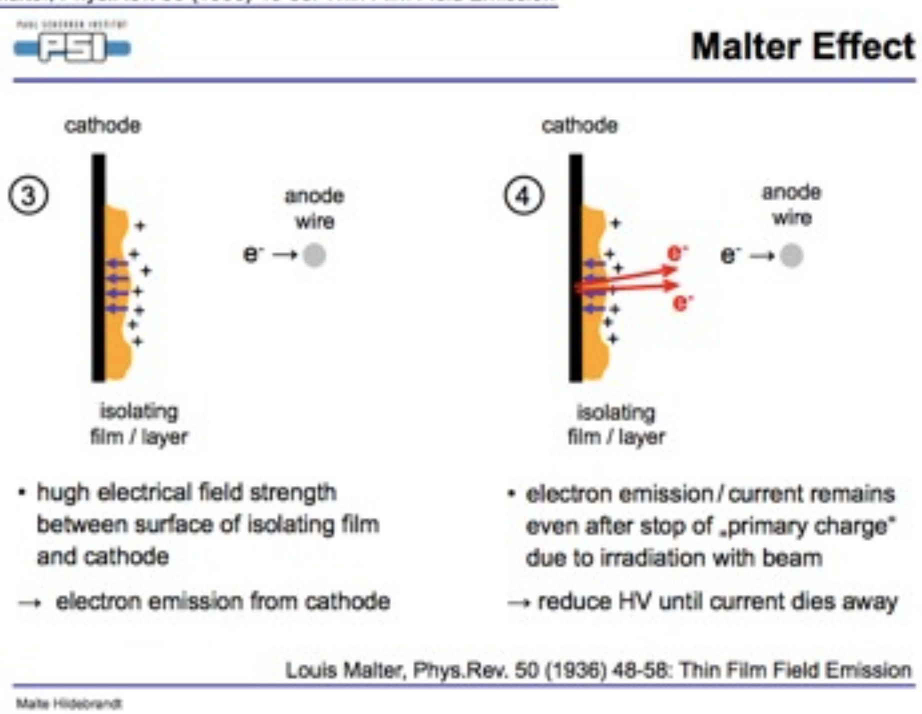
H. Fenker, The BoNuS Detector





- Current issues
  - Gas gain decreasing ?
    - may be due to growing coating on anode wires
  - Strong electric field
    - huge #of avalanche in small region
    - space charge effect
  - Malter effect
    -





Performance evaluation