Thin curved bulk Micromegas for CLAS12

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Outline

Introduction: Jefferson Lab and CLAS @ 12 GeV

CEBAF
Large
Angle
Spectrometer

Detector simulations

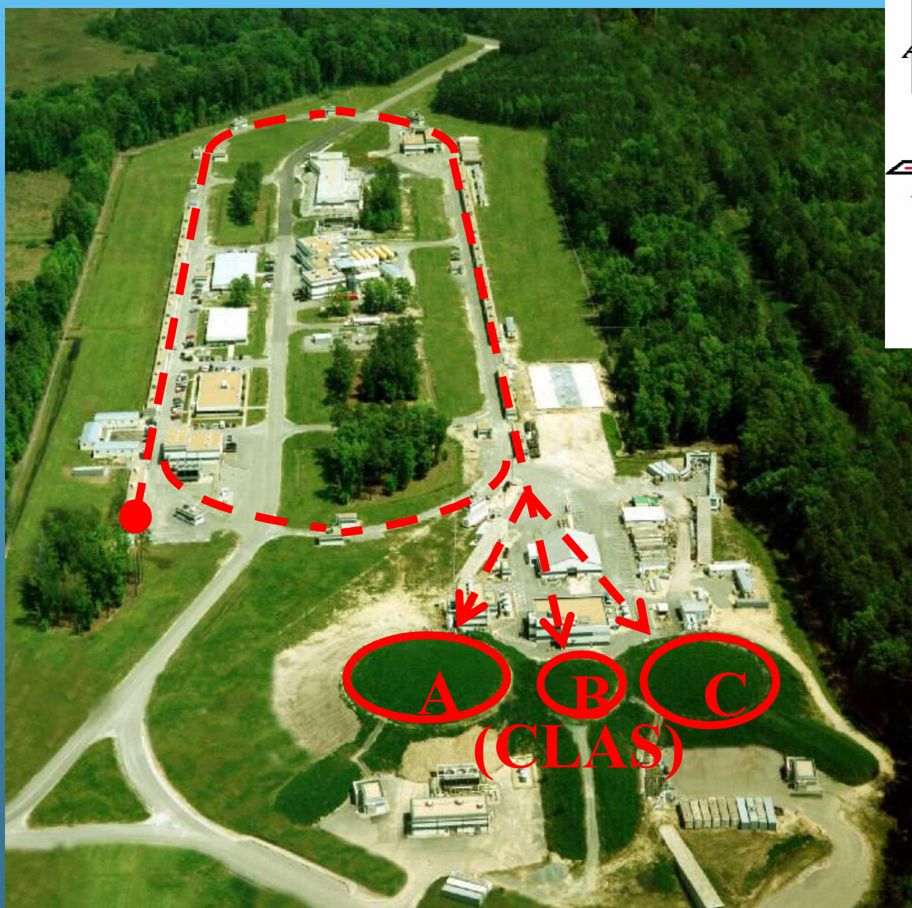
- *Optimization & characterization of the detector with Garfield*
- *Studies of the background rate with Geant4*
- *Tracking performance*

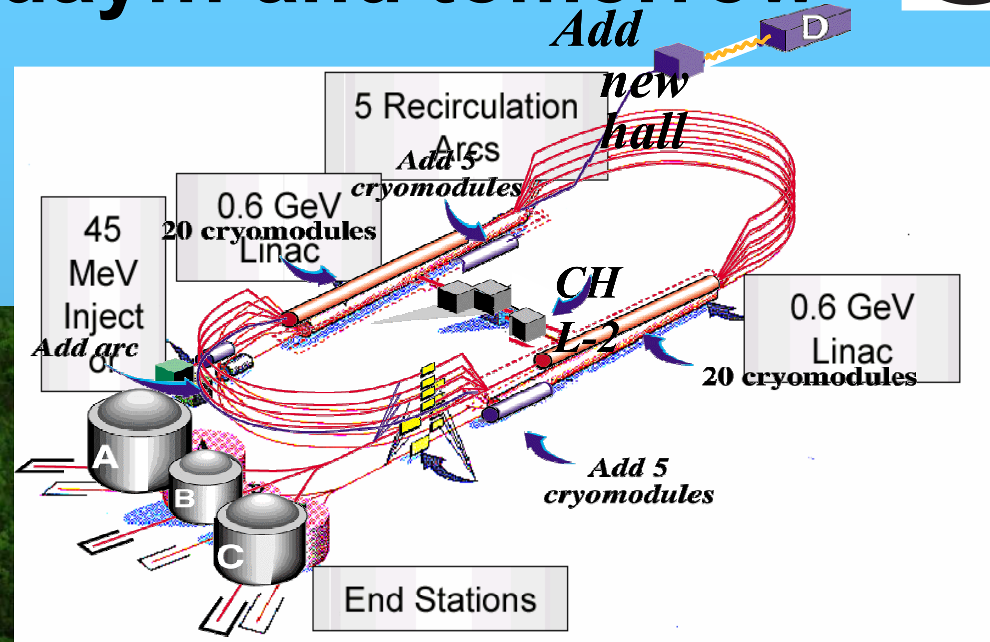
Tests of prototypes

- *Measurement of Lorentz angles up to 4.2 T field*
- *Results from cosmic rays*

Conclusion and planning of the project

Jefferson Lab today… and tomorrow





Continuous electron beam

- Energy from 0.8 to 6 GeV
- Duty factor 100%
- Beam polar ~85%
- Delivers 3 halls simultaneously

CD-3 passed last year
Construction just started
Beginning of operation: 2015

The 12 GeV project & CLAS12

Large physics program at 12 GeV:

Search for exotic mesons & origins of confinement (new Hall D)

Physics of nuclei (partonic structure, interactions from QCD principles)

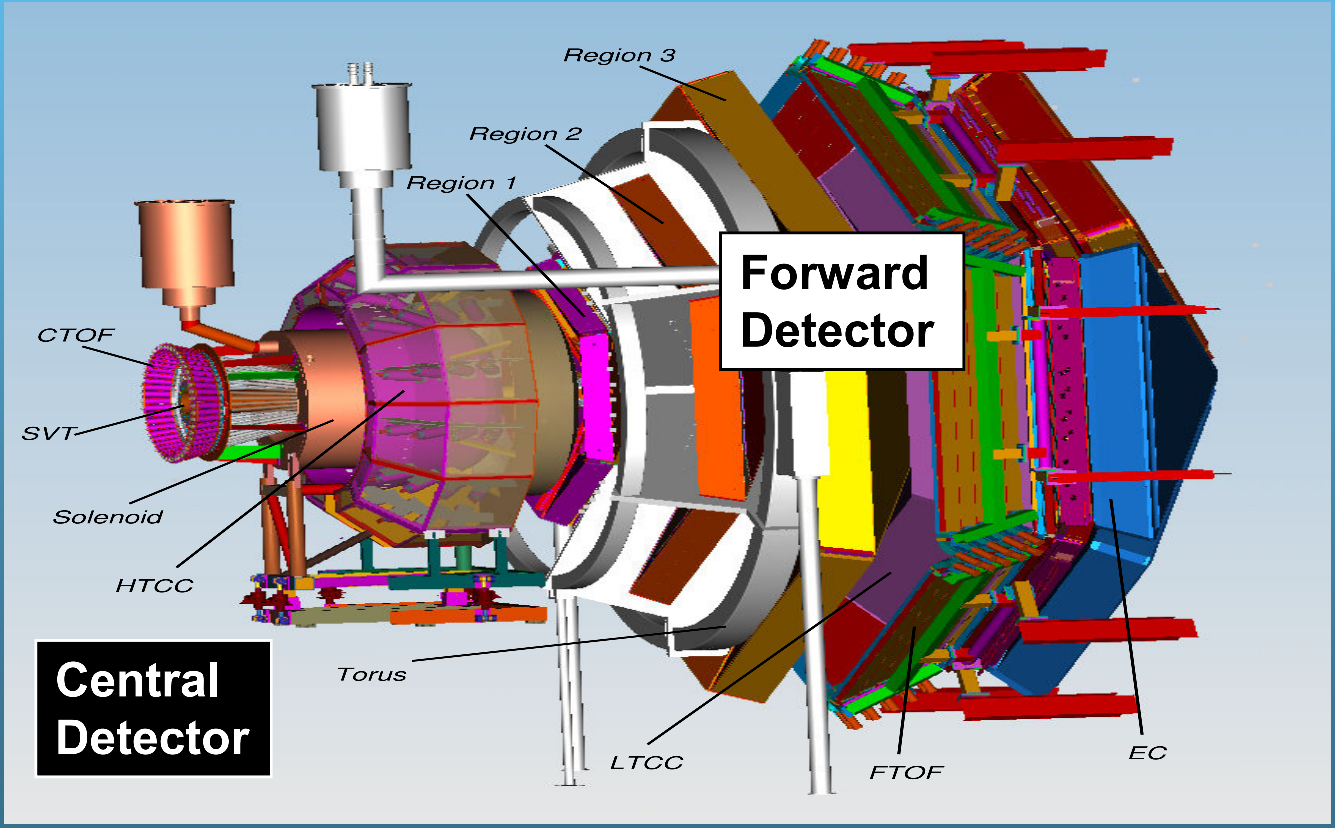
Studies of the nucleon structure (in particular mapping of GPDs)

…

Hall B needs to be upgraded → CLAS12

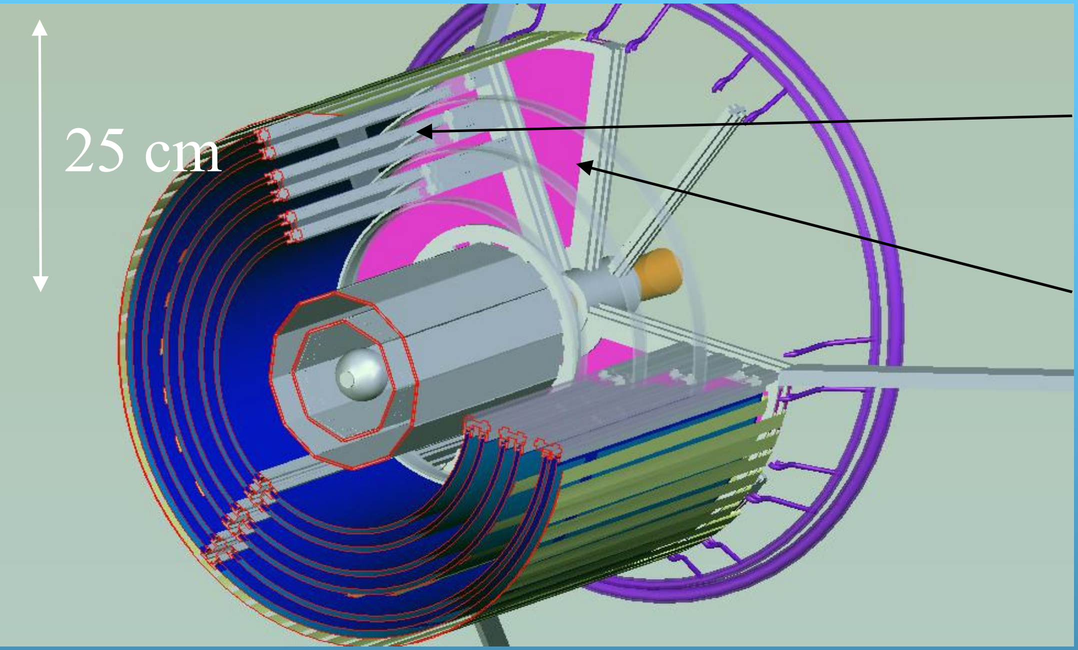
$L=10^{35}\ cm^{-2}s^{-1}$

Original design for Central Tracker:
- Barrel: 4x2 polygons of Silicons (strips at ±3°)
- Forward: 3x2 disks of Silicons (strips at ± 12°)



Micromegas for CLAS12

Proposition from Saclay to replace a large part of Si with MM bulk detectors…



3 cylindrical double layers (Barrel)

(X-Y strips at 0 and 90°)

3 flat double layers (Forward)

(U-V strips at ±30°)

$4m^2$ and ~30k channels in total

X_0 = 0.24% / layer

… but highly unfavourable conditions:

- **Barrel: large Lorentz angle (5 T transverse field)** ⇒ Decrease the drift distance / Increase the electric field / Use slow gas

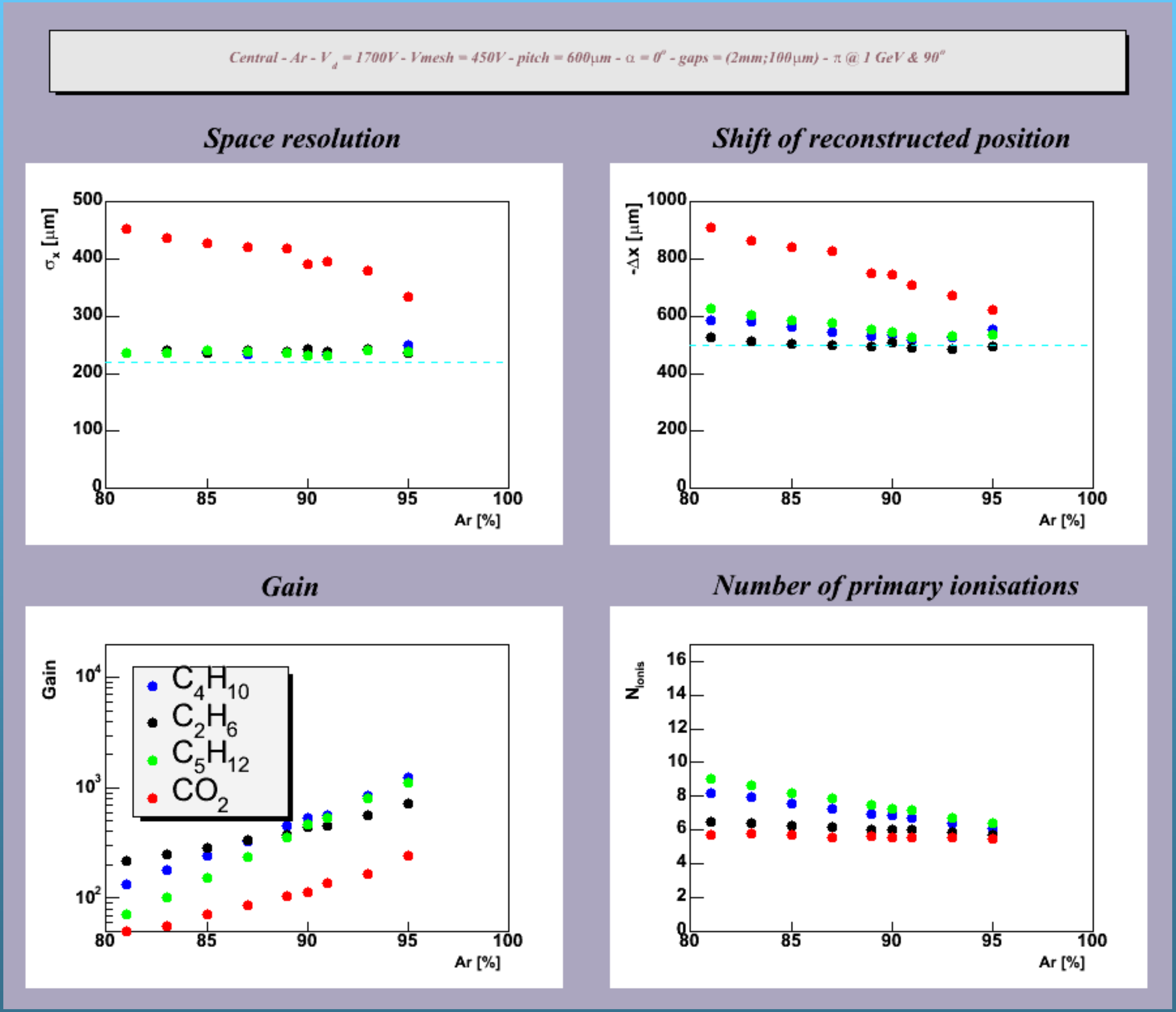
$$\tan\theta \approx v \times B / E$$

- **Forward: almost no transverse diffusion (B // E)** ⇒ Use gas with high diffusion

⇒ Garfield simulations to find the best working point (if any)

MM optimization (Barrel)

→ **Studies made with Ne (large v), Xe (heavy & expensive), Ar mixtures ⇒ Ar**



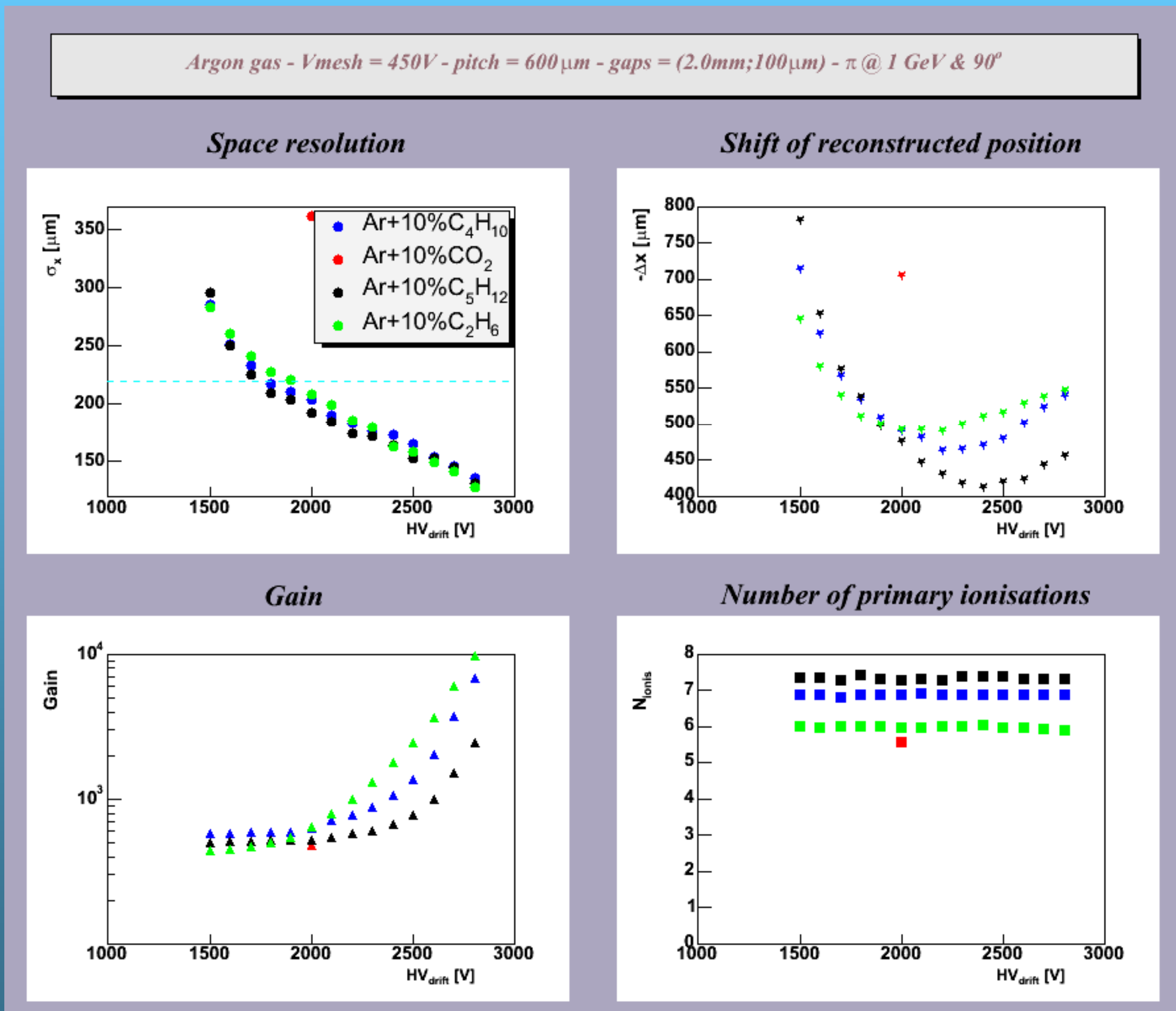
$C_4H_{10} \sim C_5H_{12} \sim C_2H_6$

Chose Ar+10%C_4H_{10}

+ Similar studies for the Forward part → Ne, CF_4

MM optimization (Barrel)

→ **Studies of the resolution with the drift high voltage**



With these conditions, pre-amplifications starts at $HV_d \approx 2000$ V

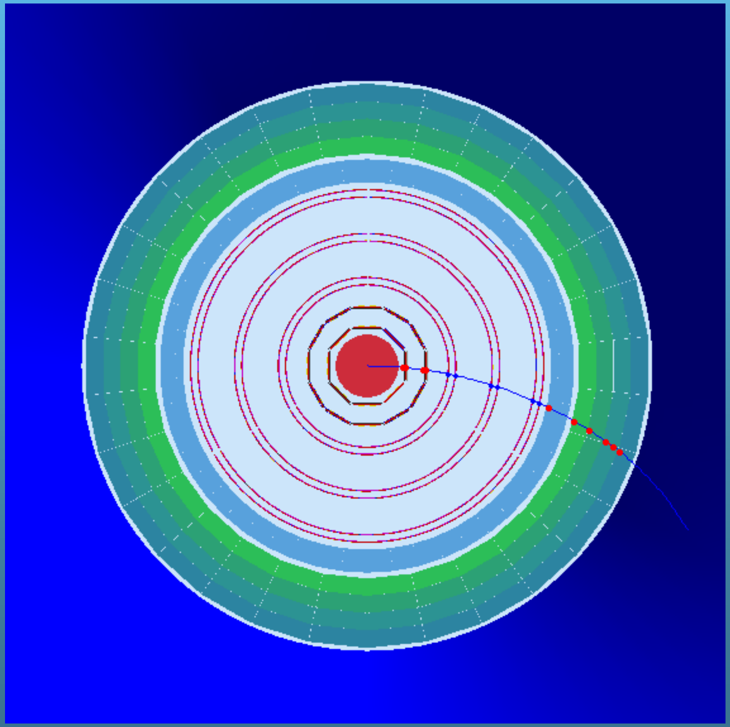
HV_d=1700 V for safety

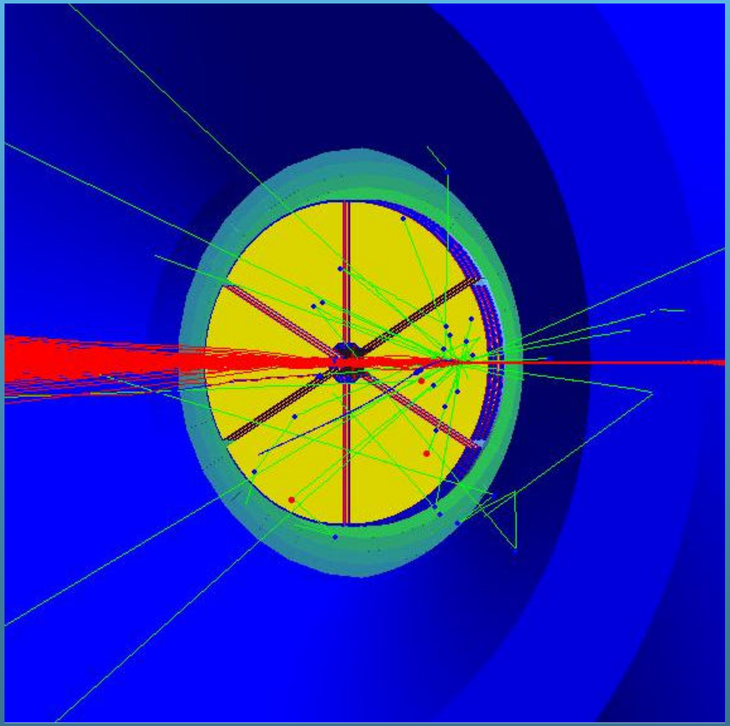
Again, separate simulations for the Forward

Geant4 simulations

→ **The main goal is to determine the background rate seen by the MM at the CLAS12 luminosity**

- **Barrel: 2 double layers of Si + 3 double layers of cylindrical MM**
- **Forward: 3 double layers of flat MM**





Geant4 simulations

→ Using 62,500 beam electrons (⇔132 ns time window, very conservative):

Strip rates in MHz in the Barrel

Si	Layer 1	Layer 2	Layer 3	Layer 4
e-/e+	3.9	3.7	4.3	4.3
photon	30.5	22.0	25.7	20.0
hadron	1.6	1.3	1.7	1.5
total	36.2	27.0	31.9	26.0

MM	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
e-/e+	1.27	2.73	1.14	2.92	1.70	3.68
photon	0.08	0.03	0.07	0.06	0.09	0.08
hadron	0.96	0.95	1.13	1.11	0.91	0.84
total	2.40	3.80	2.40	4.15	2.77	4.66

Strip rates in MHz in the Forward (Si in parenthesis)

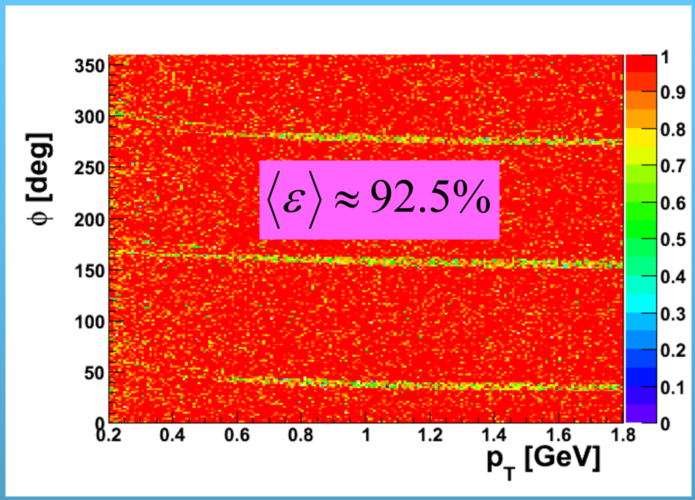
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
e-/e+	7.6 (7.5)	4.7 (6.4)	4.7 (6.6)	4.0 (7.3)	4.0 (7.2)	3.6 (7.5)
photon	2.0 (13.9)	0.2 (11.3)	0.2 (9.5)	0.1 (8.3)	0.1 (7.1)	0.1 (5.7)
hadron	2.2 (1.6)	2.1 (1.5)	2.0 (1.4)	2.0 (1.4)	1.9 (1.4)	1.8 (1.3)
total	12.0 (23.1)	7.2 (19.3)	7.0 (17.7)	6.2 (17.1)	6.1 (15.8)	5.5 (14.6)

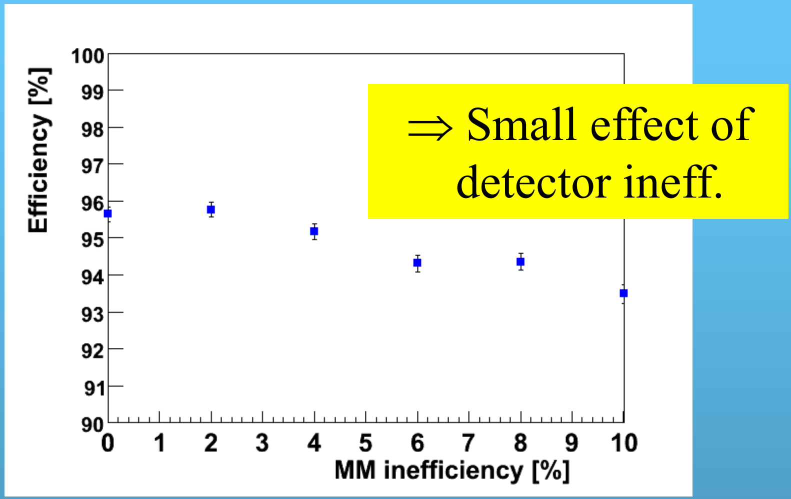
→ **Significantly smaller rates in MM than in Si, essentially due to photon rate**

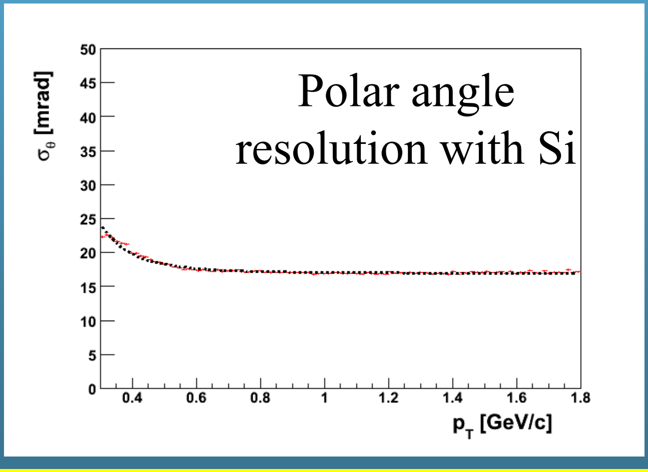
→ ***A fortiori*** **no problem for tracking (already proven for Silicon design)**

Tracking performance (Barrel)

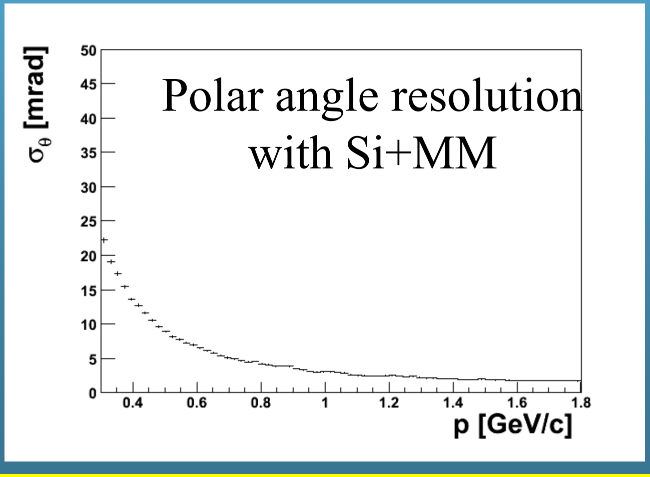
→ **performance estimated with Kalman Filter algorithm developed for CLAS12**



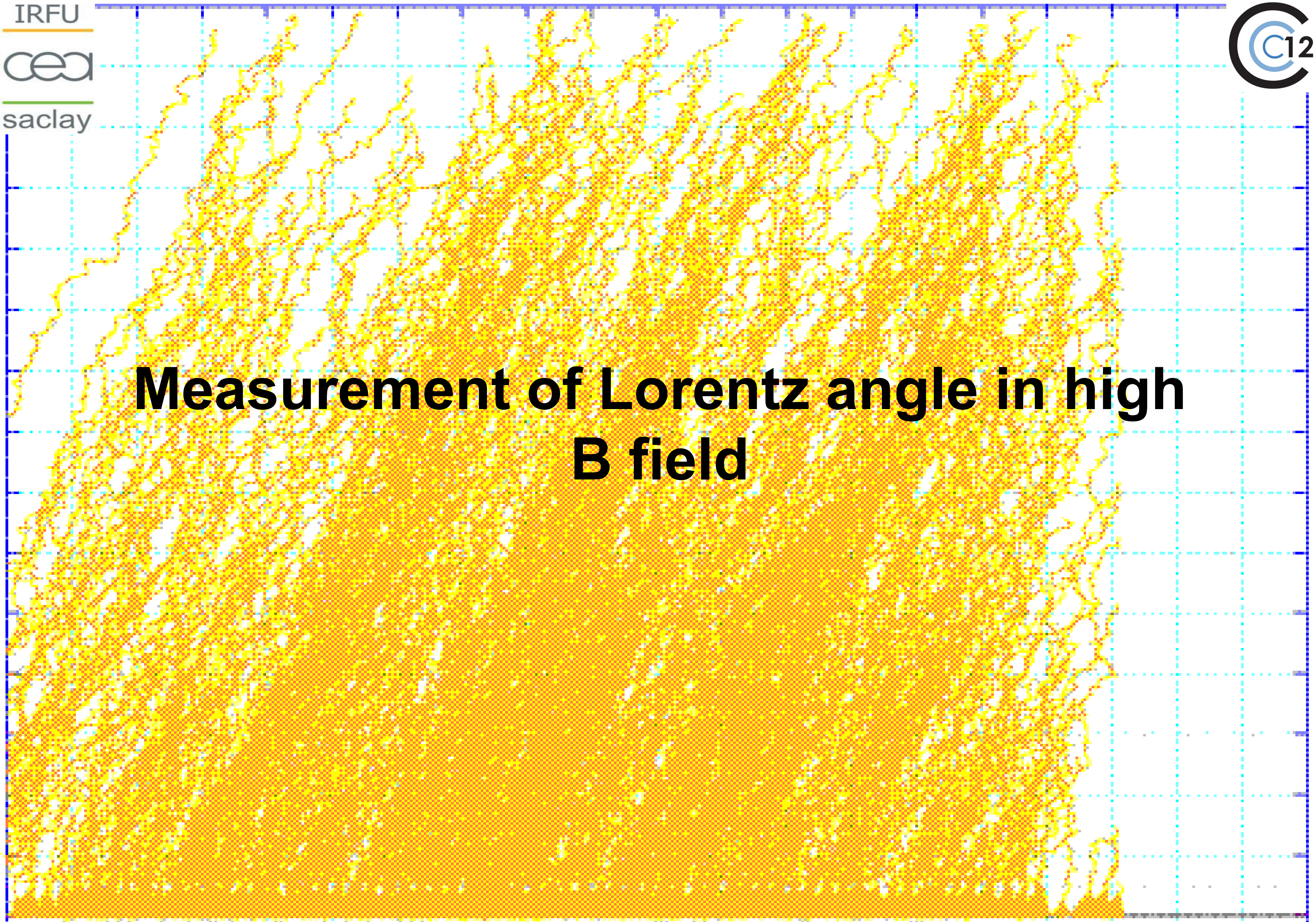




→

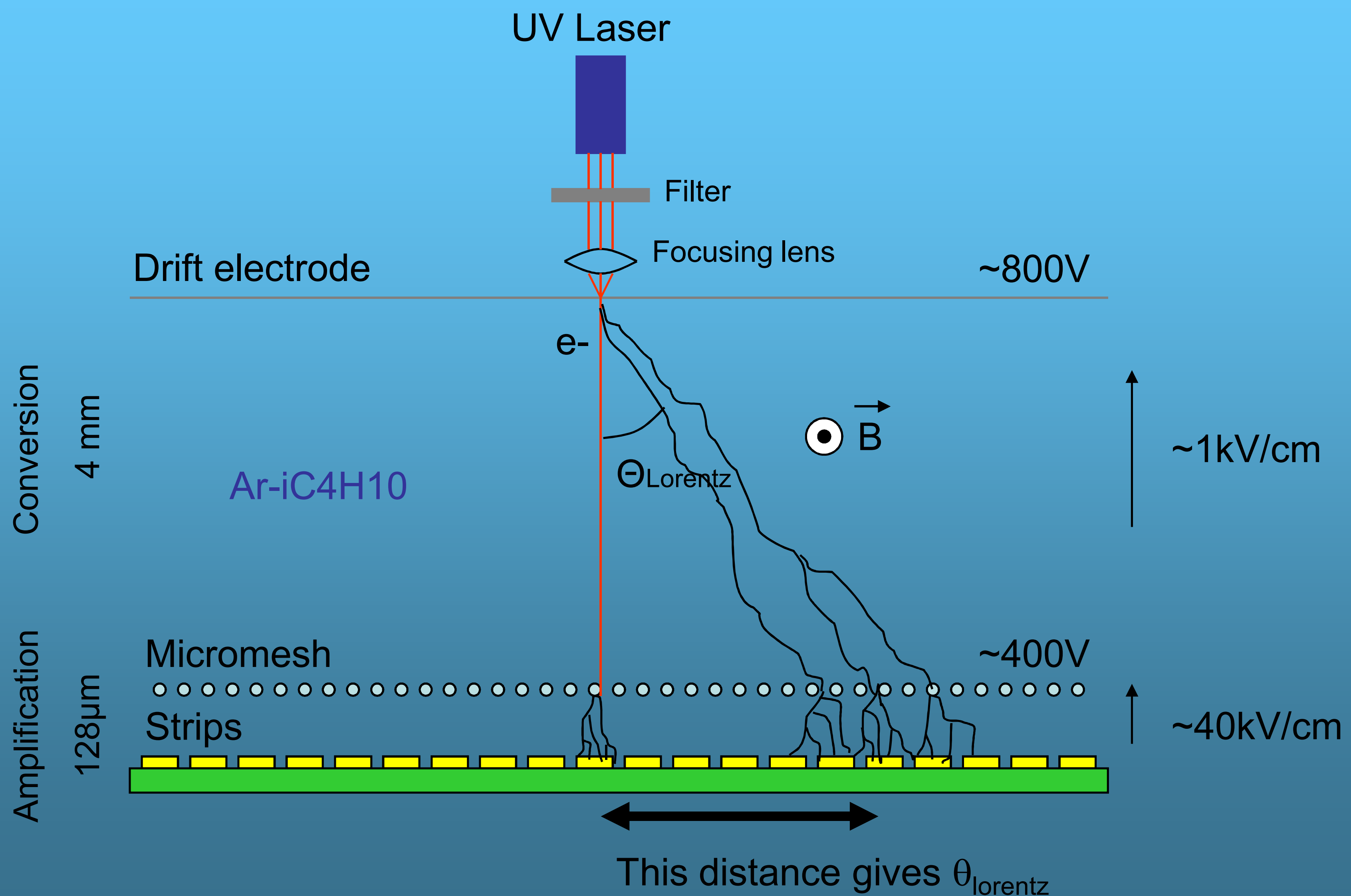


⇒ Much better θ resolution, without any degradation on other variables

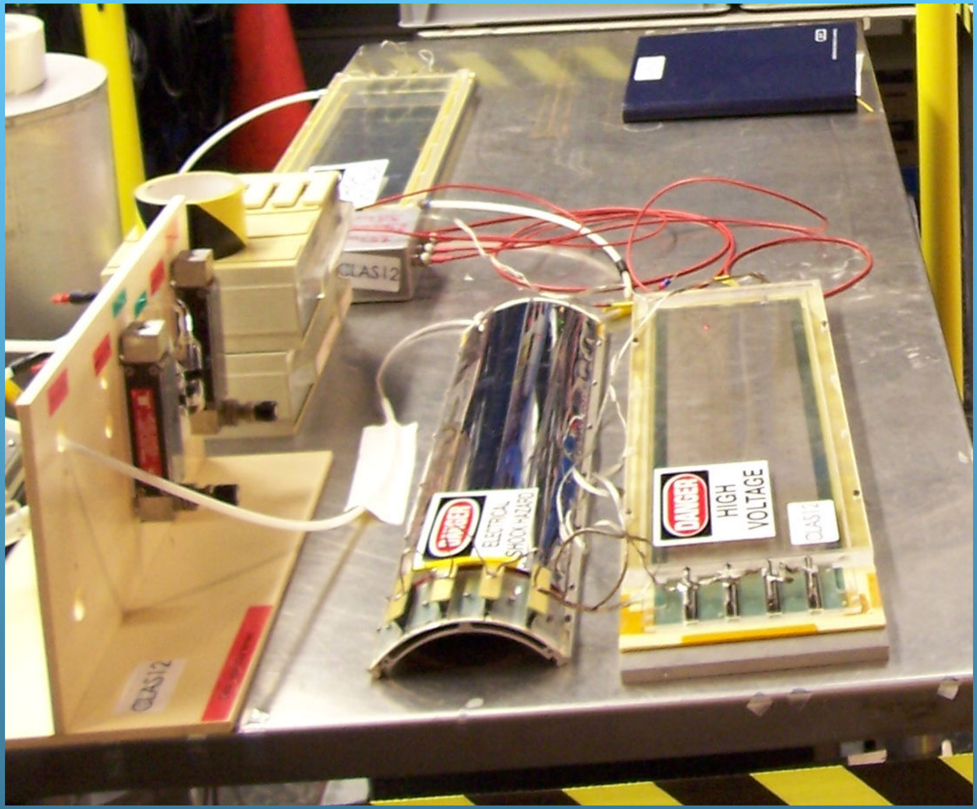


Measurement of Lorentz angle in high B field

Measurement principle

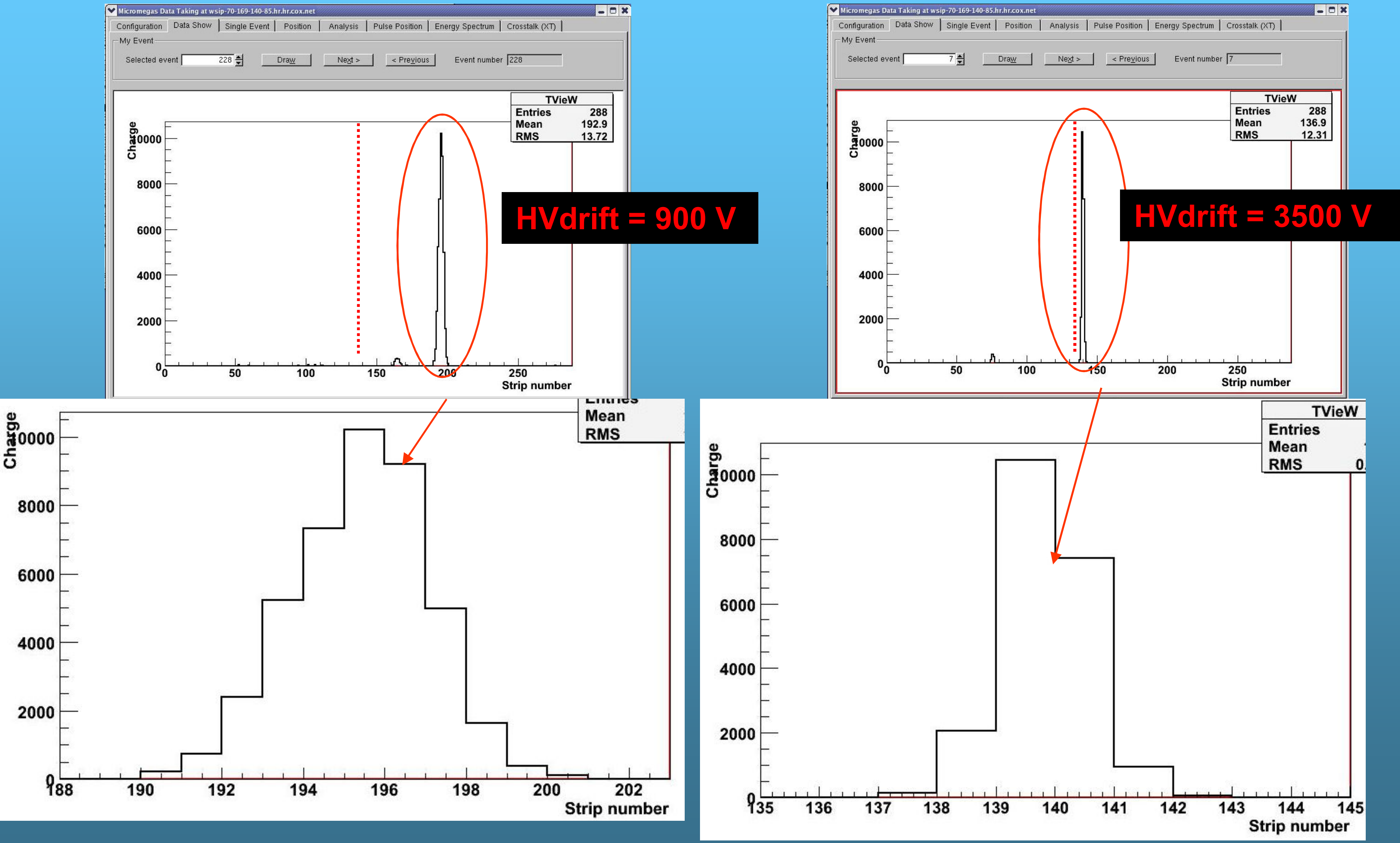


Prototype characteristics

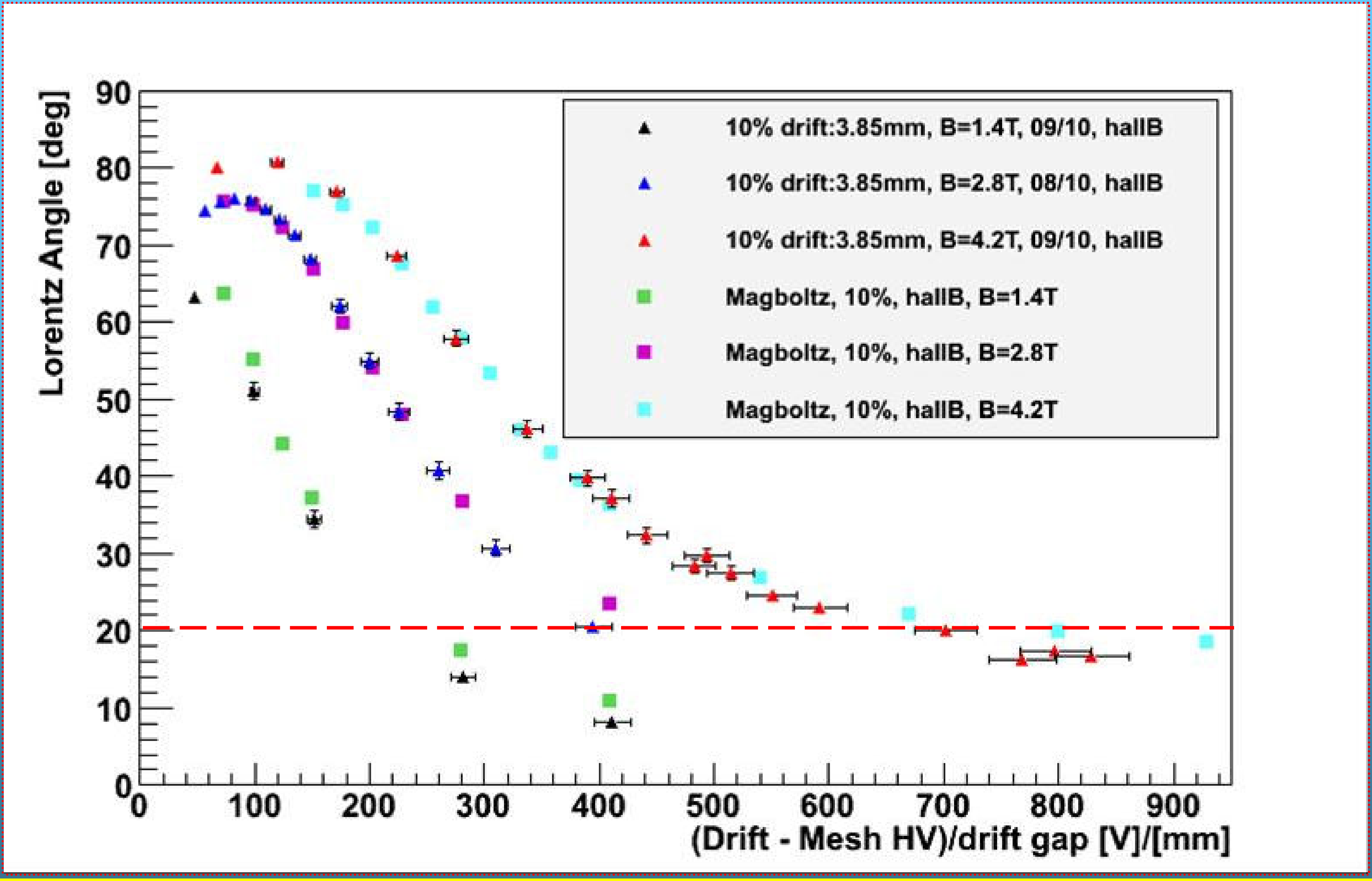


- Drift : Al-mylar
- Drift gap : 3.85mm
- 4*72 strips
- Pitch : 0.4mm
- Data acquisition : T2K electronics (FEC+FEM) + DAQ
- 90% Ar + 10% iC_4H_{10}

Signal at 4.2 T

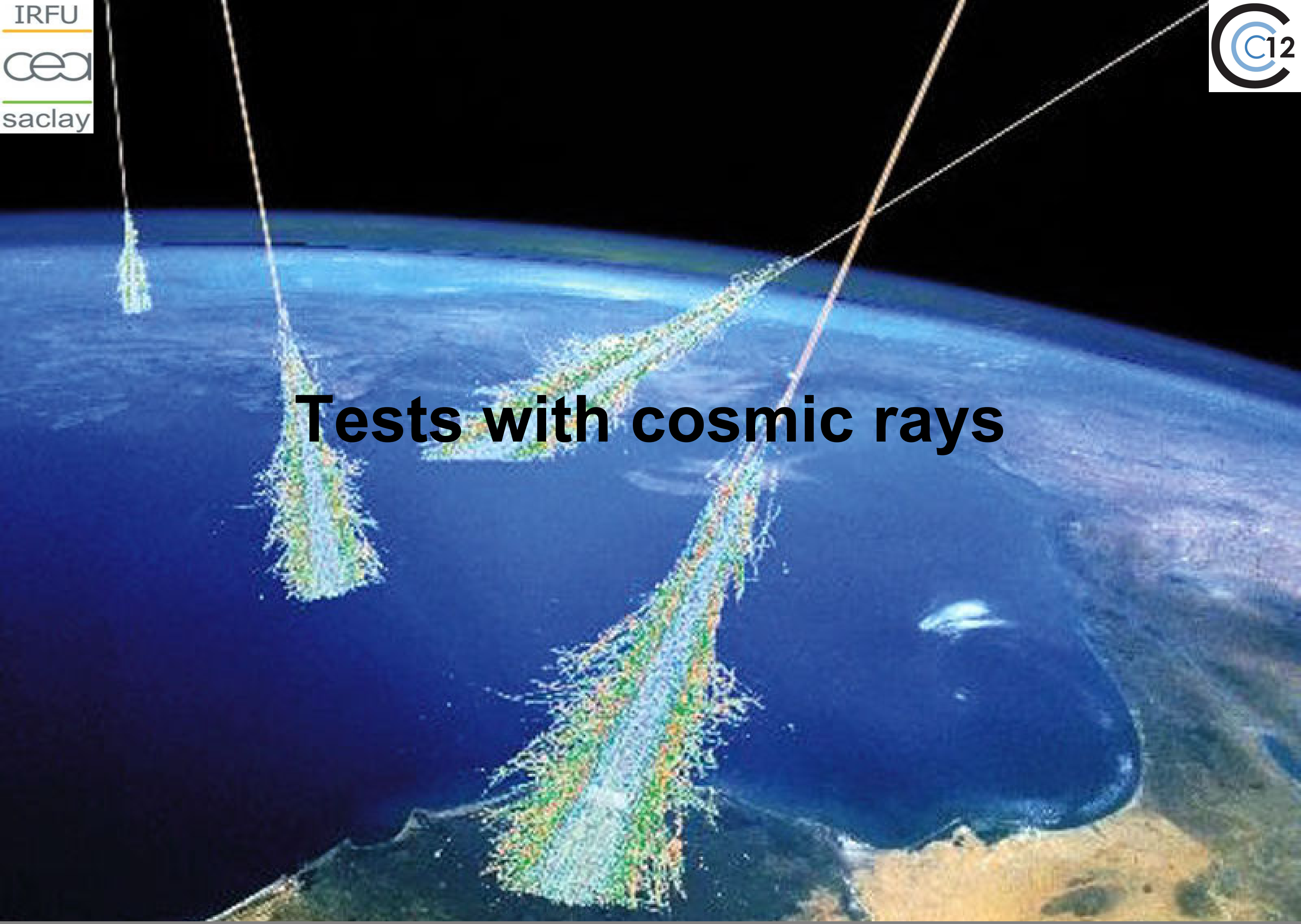


Results on Lorentz angle

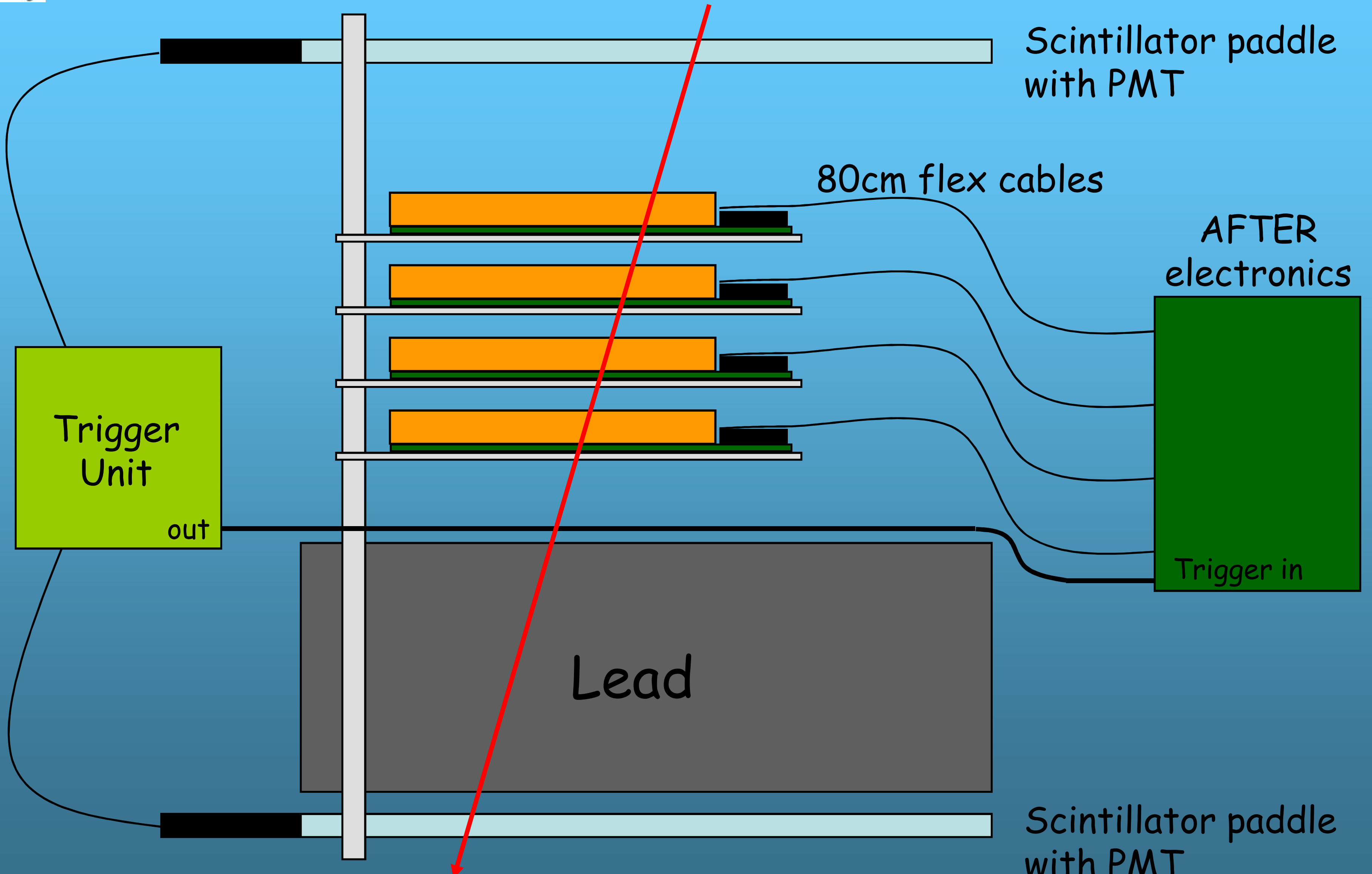


⇒ **Good agreement with the simulation (and 1st measurement at such high B fields)**

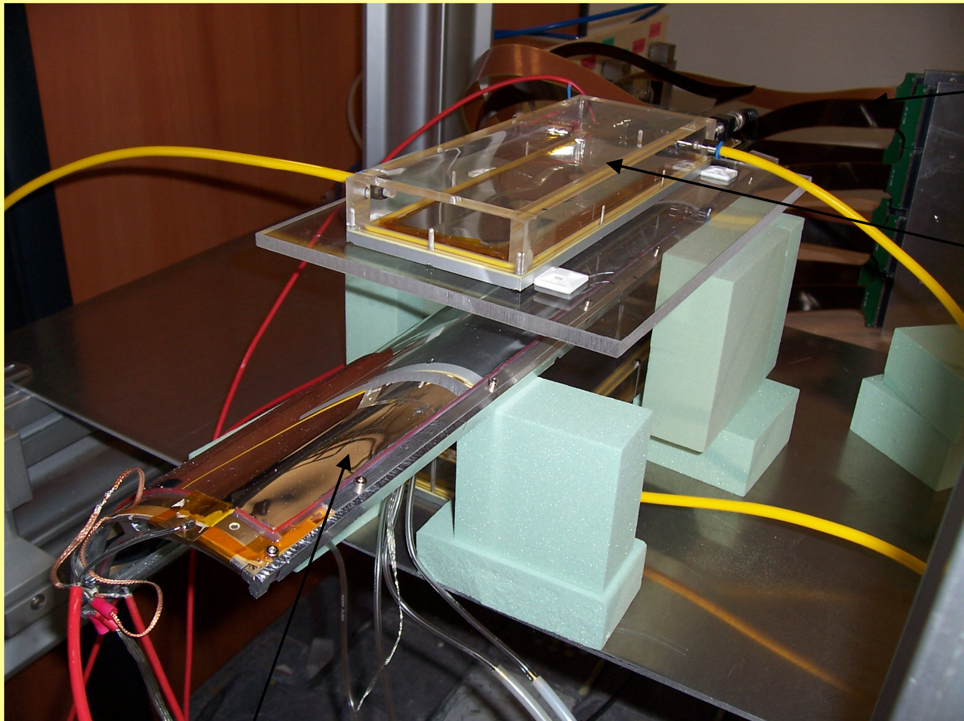
Tests with cosmic rays



Experimental setup (Saclay)

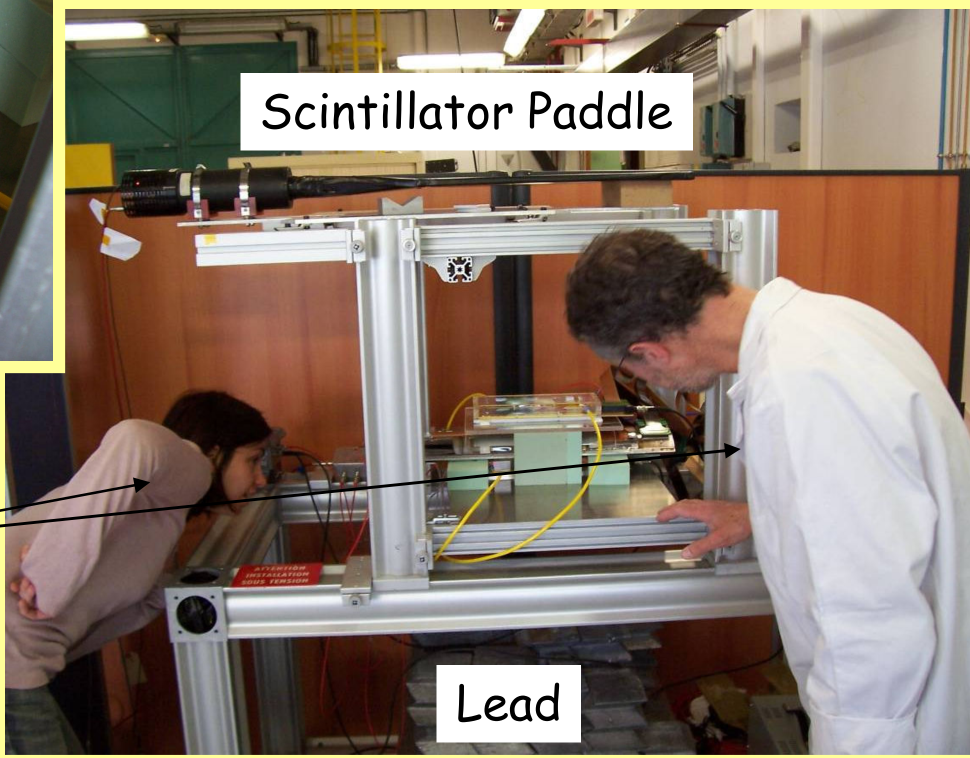


Saclay cosmic ray bench



Flex cables

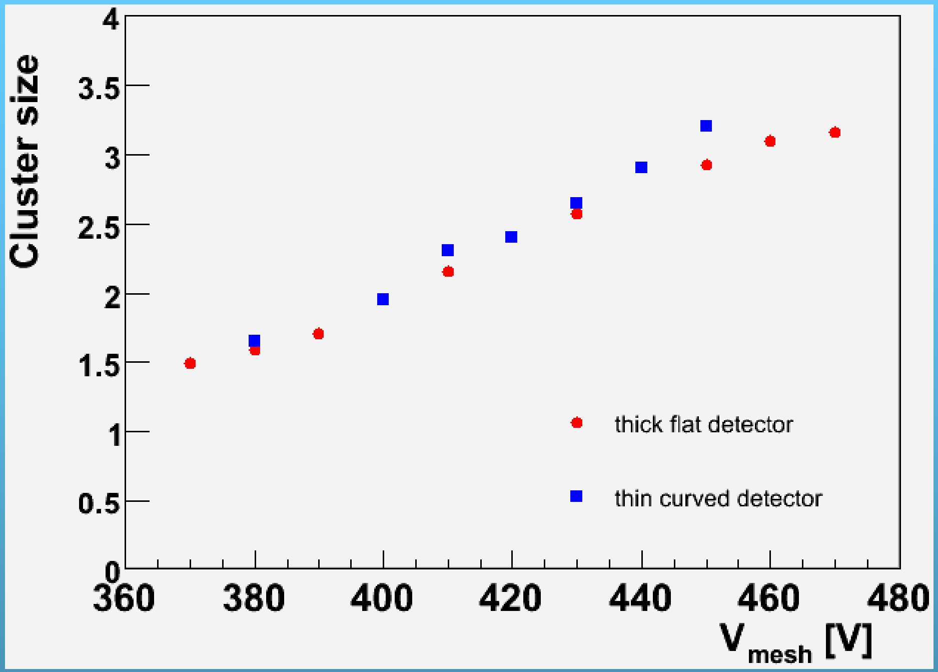
Reference detector



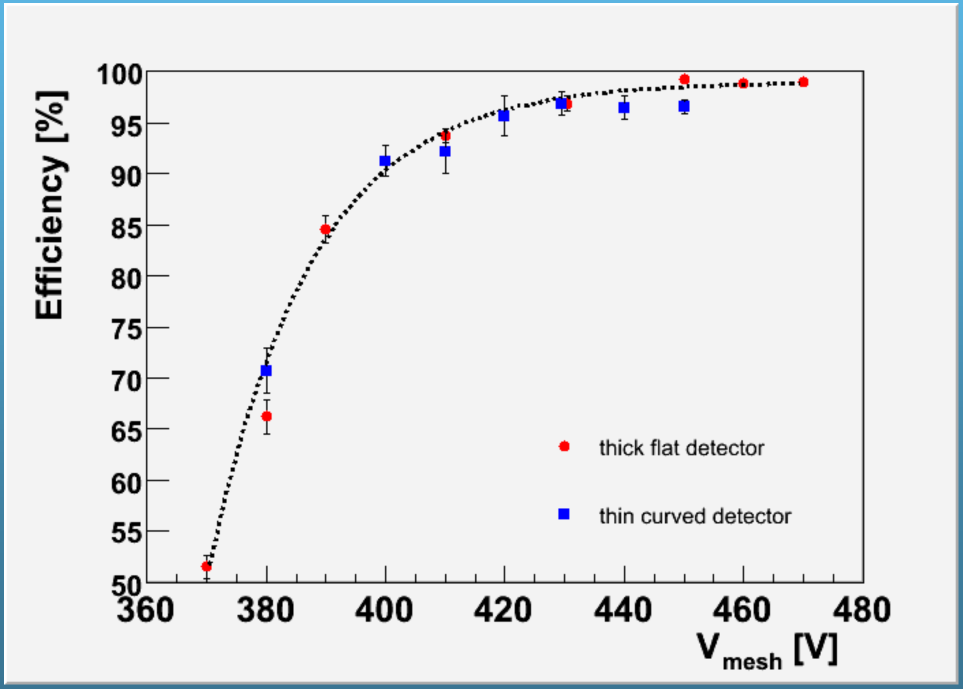
Micrometric alignment

Curved detector
(demonstrator)

Flat vs curved Micromegas - 1

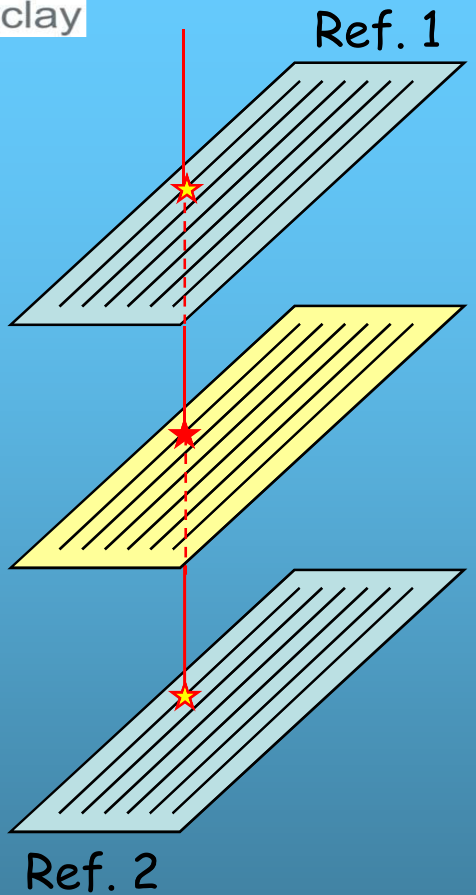


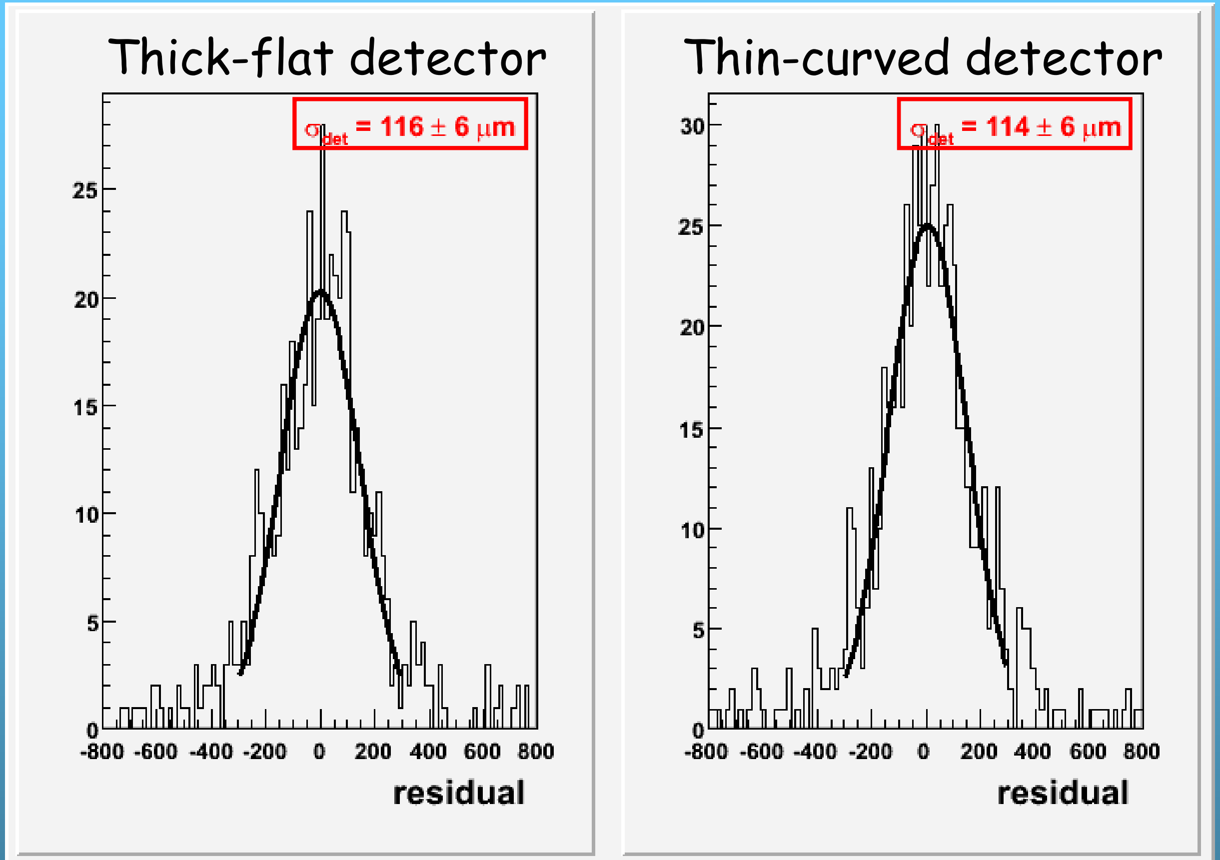
Very similar multiplicity (a little larger because of track angles)



Similar plateau with curved detector, though a little shorter

Flat vs curved Micromegas - 2



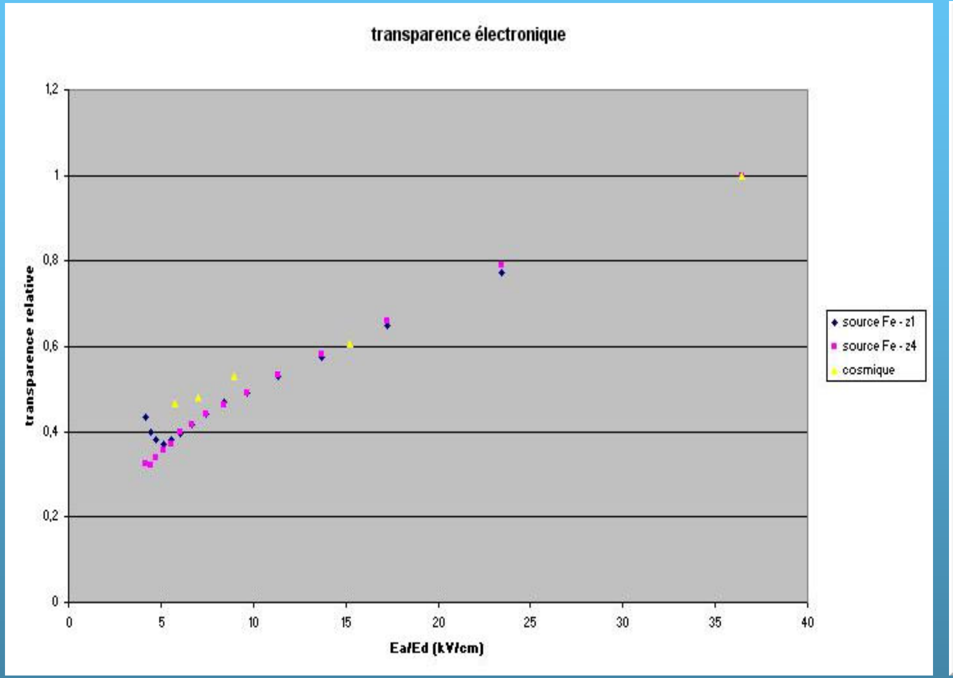


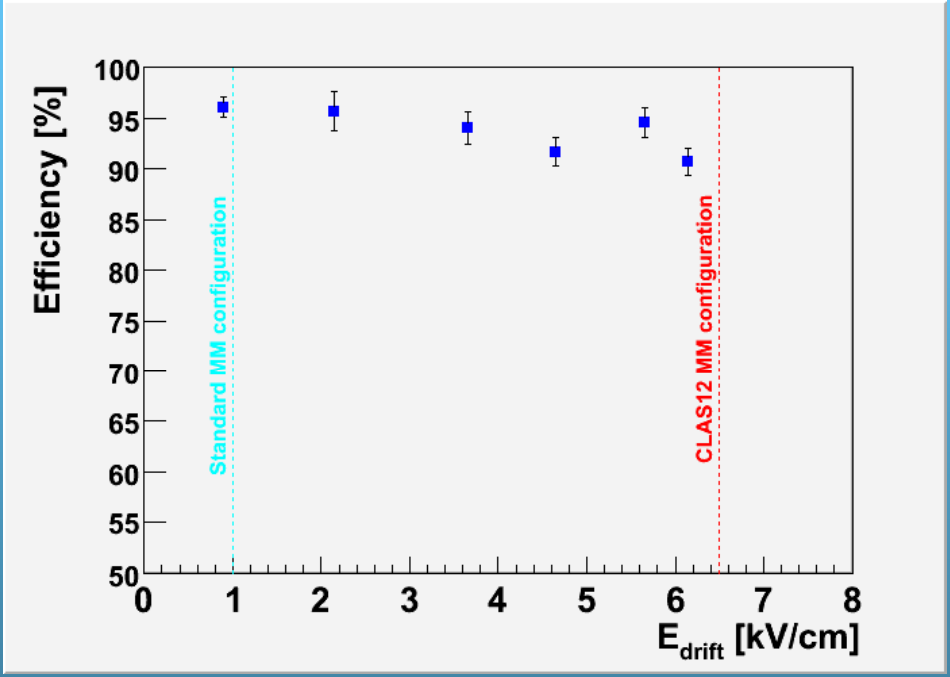
(Probably some misalignments wrt reference detectors… will do better soon with X-Y detectors)

⇒ Almost no performance differences between flat and curved detectors

Transparency and efficiency

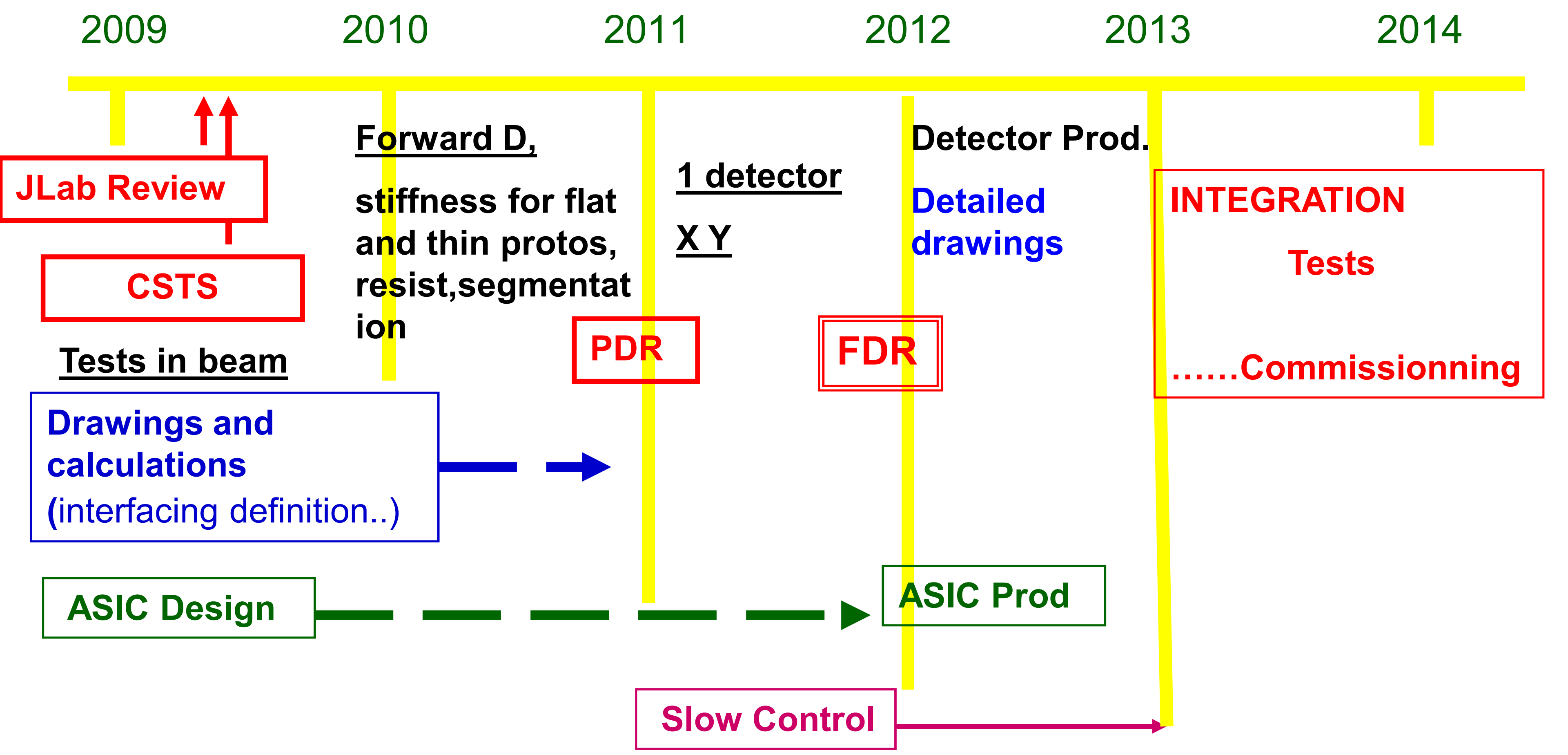
Effect of the drift field increase on the transparency and efficiency





⇒ Transparency is only around 40%, but only a few % effect on the efficiency

Schedule



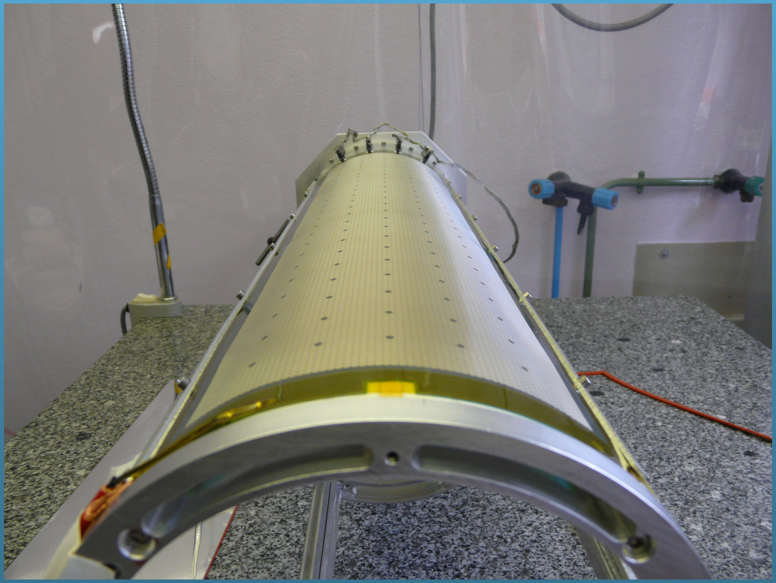
2009
2010
2011
2012
2013
2014
JLab Review
CSTS
Tests in beam
Forward D,
stiffness for flat and thin protos, resist,segmentation
1 detector
X Y
PDR
FDR
Detector Prod.
Detailed drawings
INTEGRATION
Tests
……Commissionning
Drawings and calculations
(interfacing definition..)
ASIC Design
ASIC Prod
Slow Control

Conclusion

- Report on the "Review of Micromegas Tracking Detectors for CLAS12" held May 7, 2009 @ JLab

…*We find that the simulated performance for resolution, solid angle coverage and efficiency will meet or exceed CLAS12 requirements*

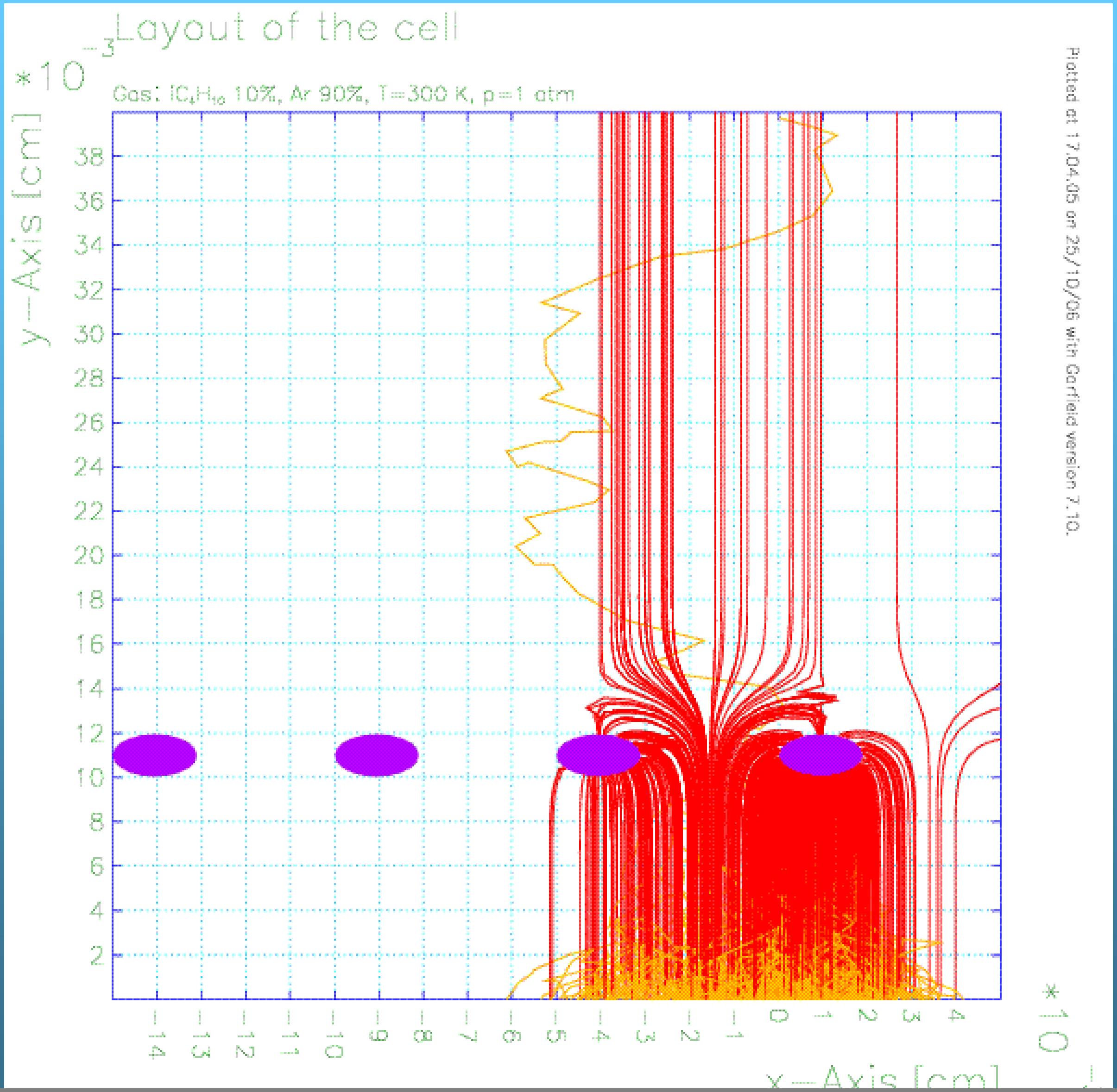
We see no major obstacles to construction of a successful central tracking system based on the presented conceptual design.



Backup

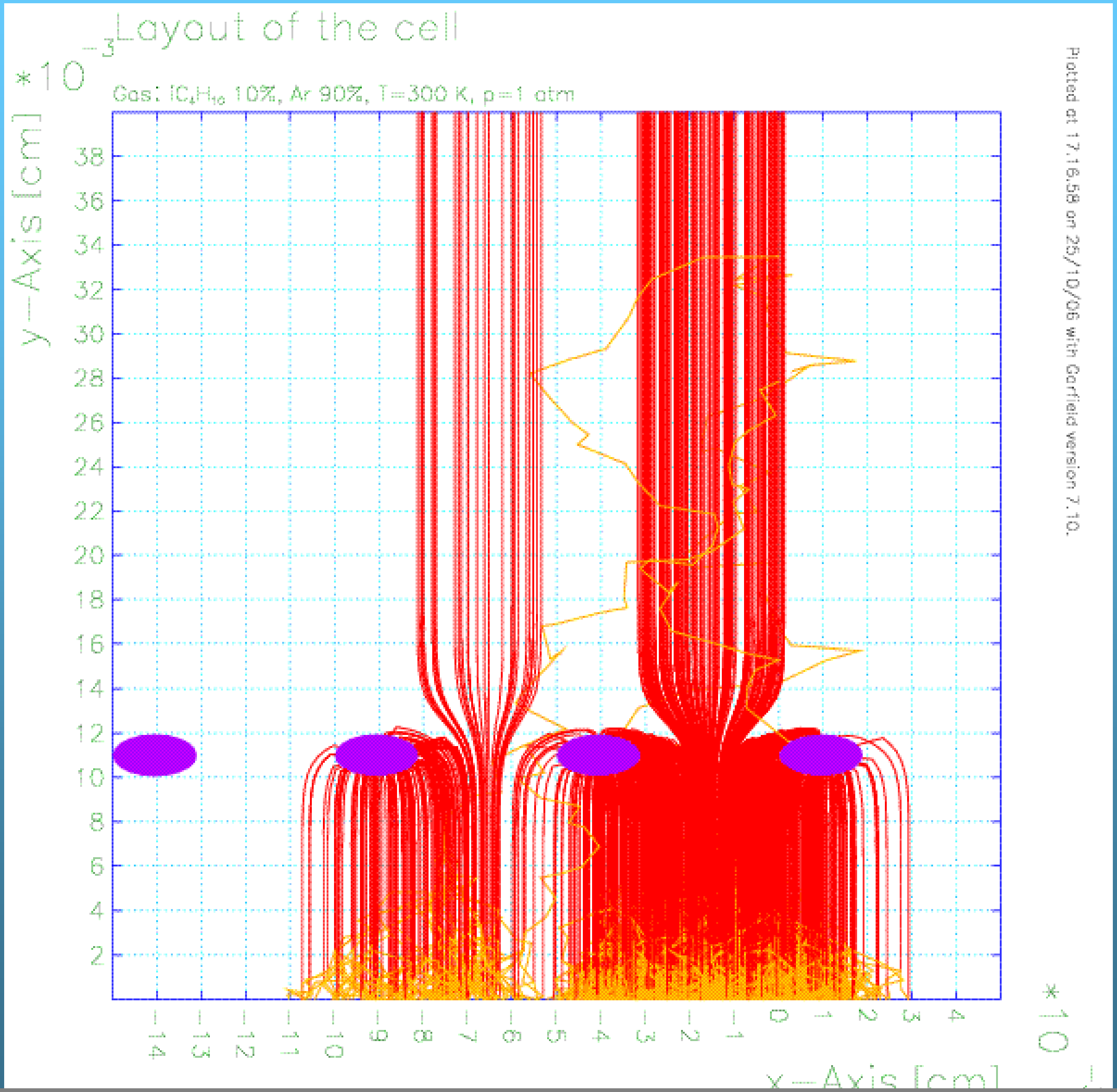
Ion transparency-1

HV_d = 720 V
HV_m = 450 V



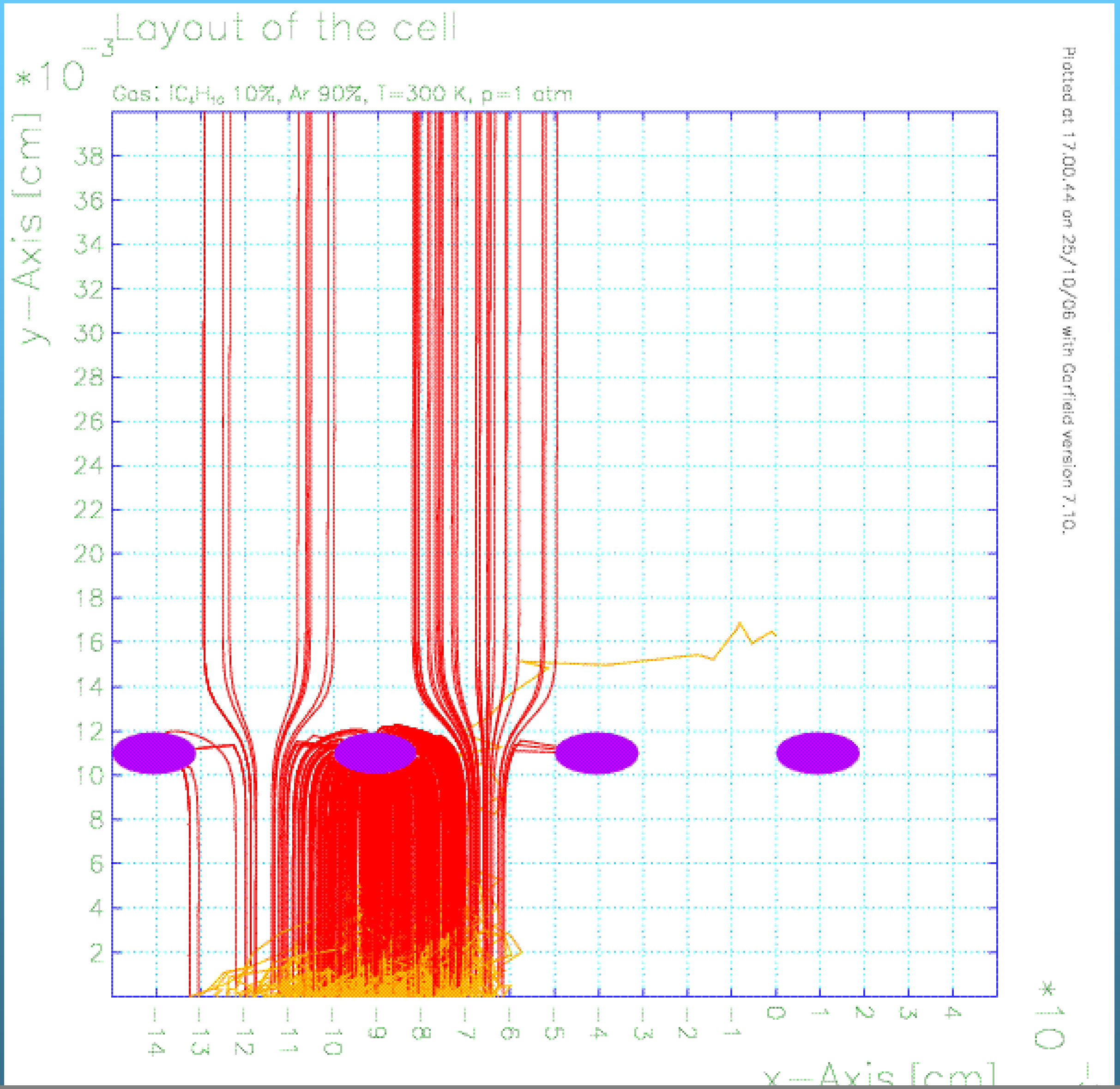
Ion transparency-2

$HV_d = 2000$ V
$HV_m = 450$ V

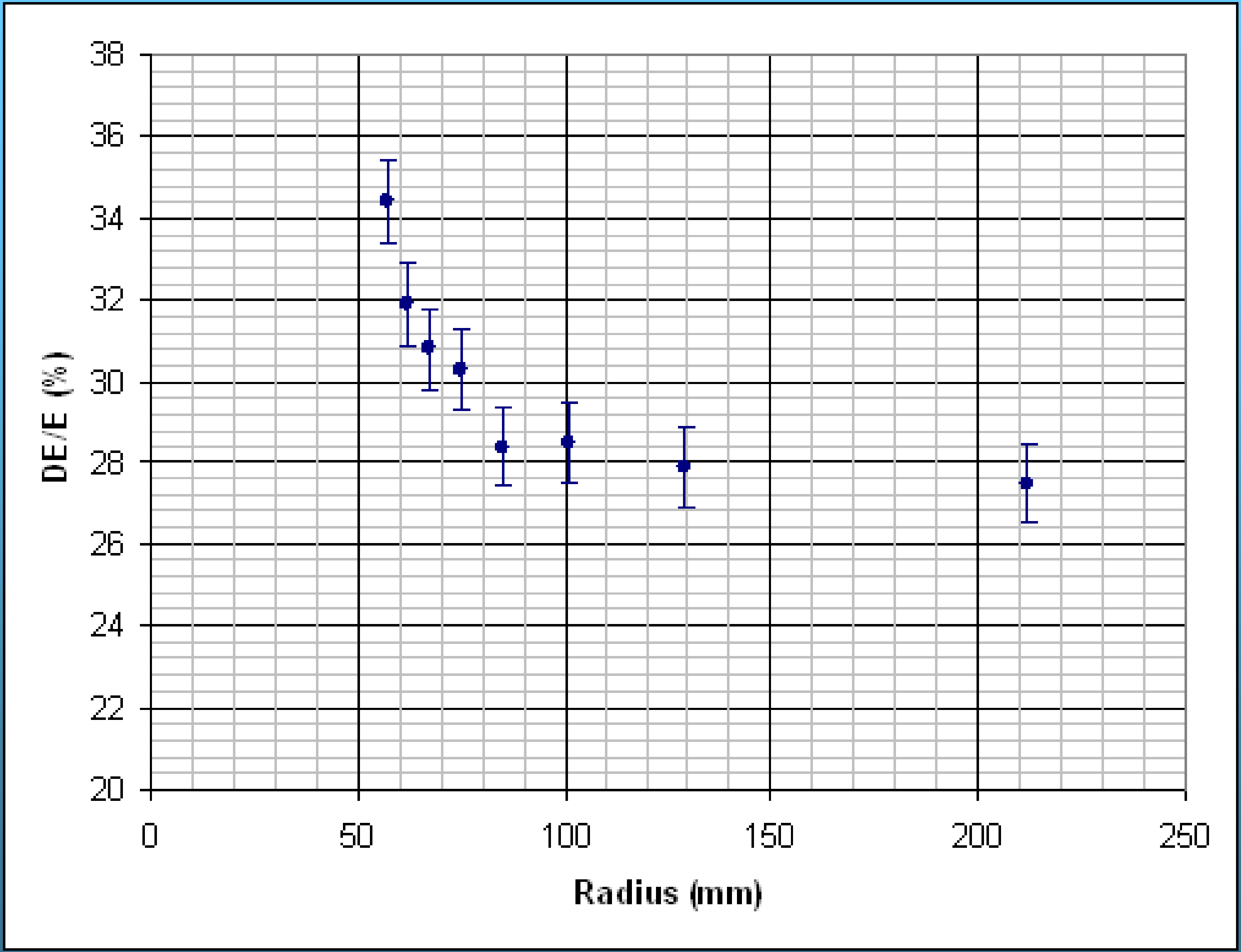


Ion transparency-3

HV_d = 2000 V
HV_m = 450 V
B = 5 T

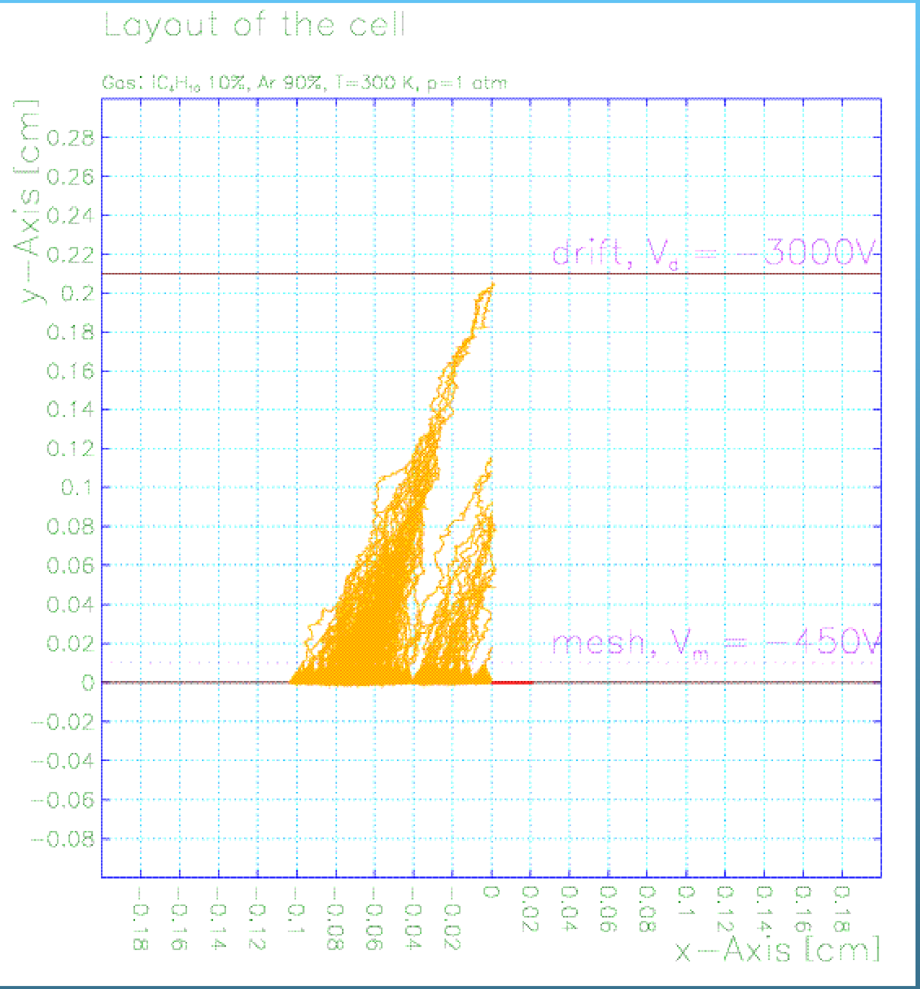


Energy resolution vs radius



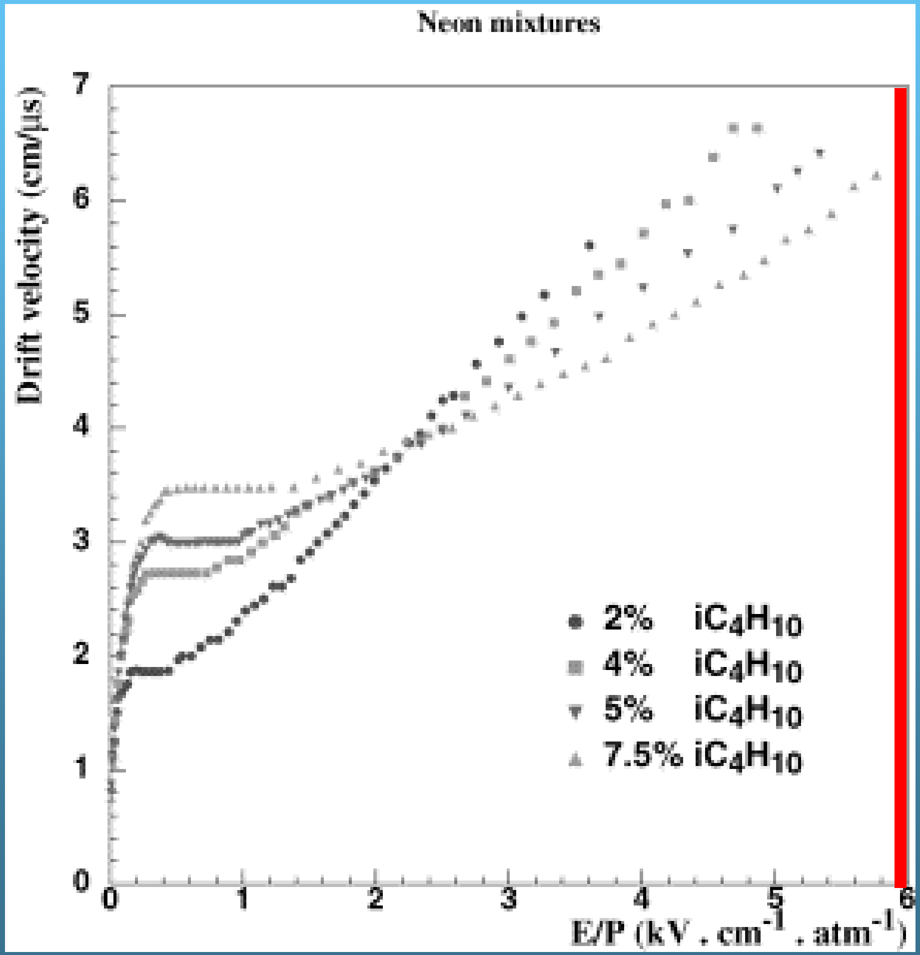
Increase electric field

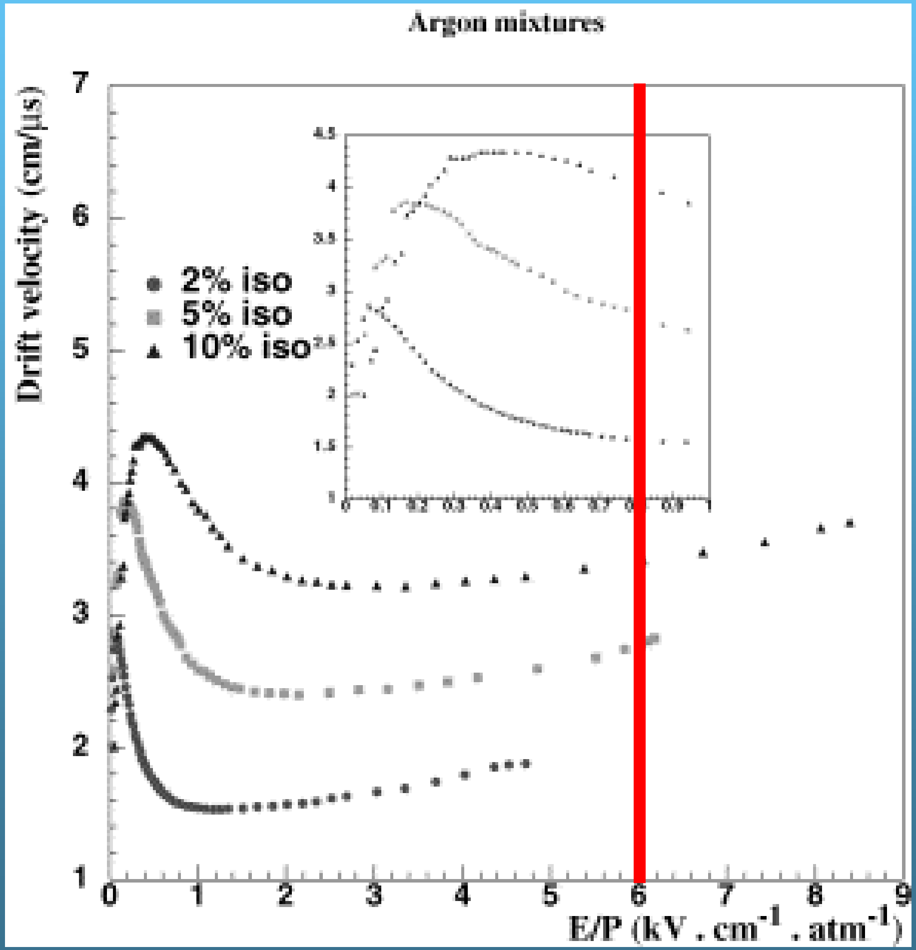
$$\tan\theta_L = \frac{v(E,B)\times B}{E}$$



Use slow gas

$$\tan\theta_L = \frac{v(E,B)\times B}{E}$$





Flex cable noise studies