Tracking system based on GEM chambers

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and

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PAVI 11

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GEM Technology

JLab/Hall A current project

MPGD alternatives

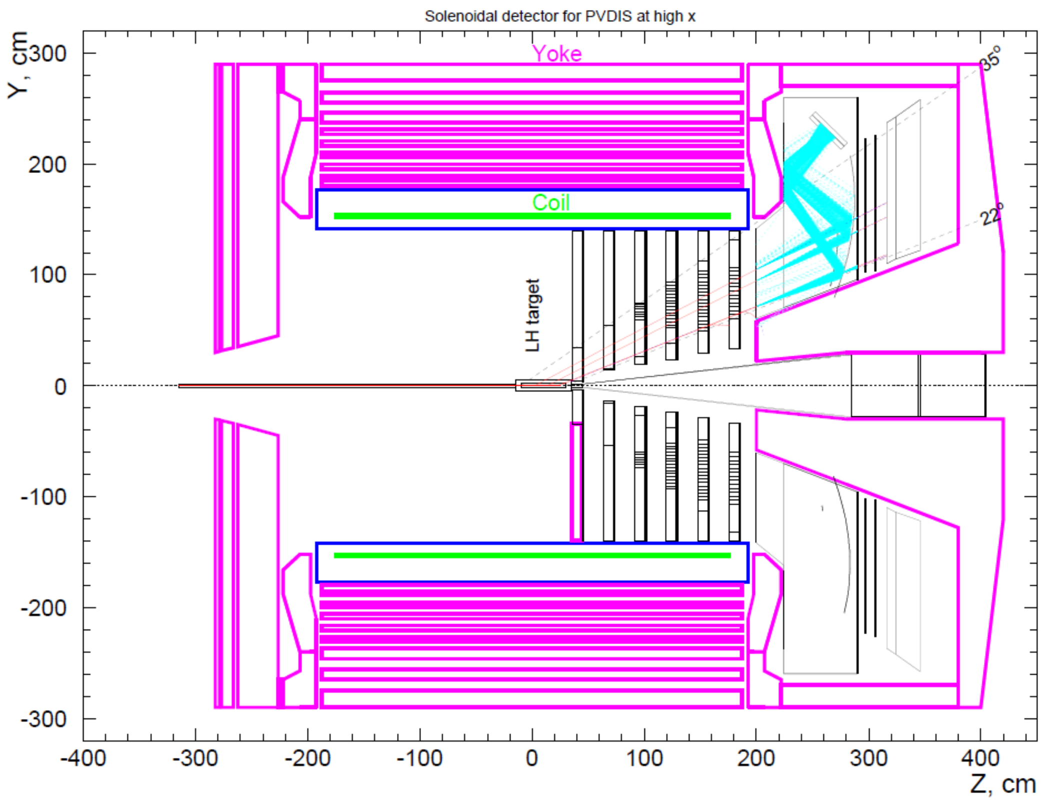
Conclusions

GEM Technology

Tracking in PVDIS/SOLID @ JLab12

- Rate: from 100 kHz to 600 kHz (with baffles), GEANT3 estimation
- Spatial Resolution: ~0.2 mm (sigma)
- Total area: 23 m^2 total area (30 sectors x4 planes, each sector cover 10 degree)
- Magnetic field tolerant

Lumi = 5.4E38 /cm^2/s



Choice of the technology

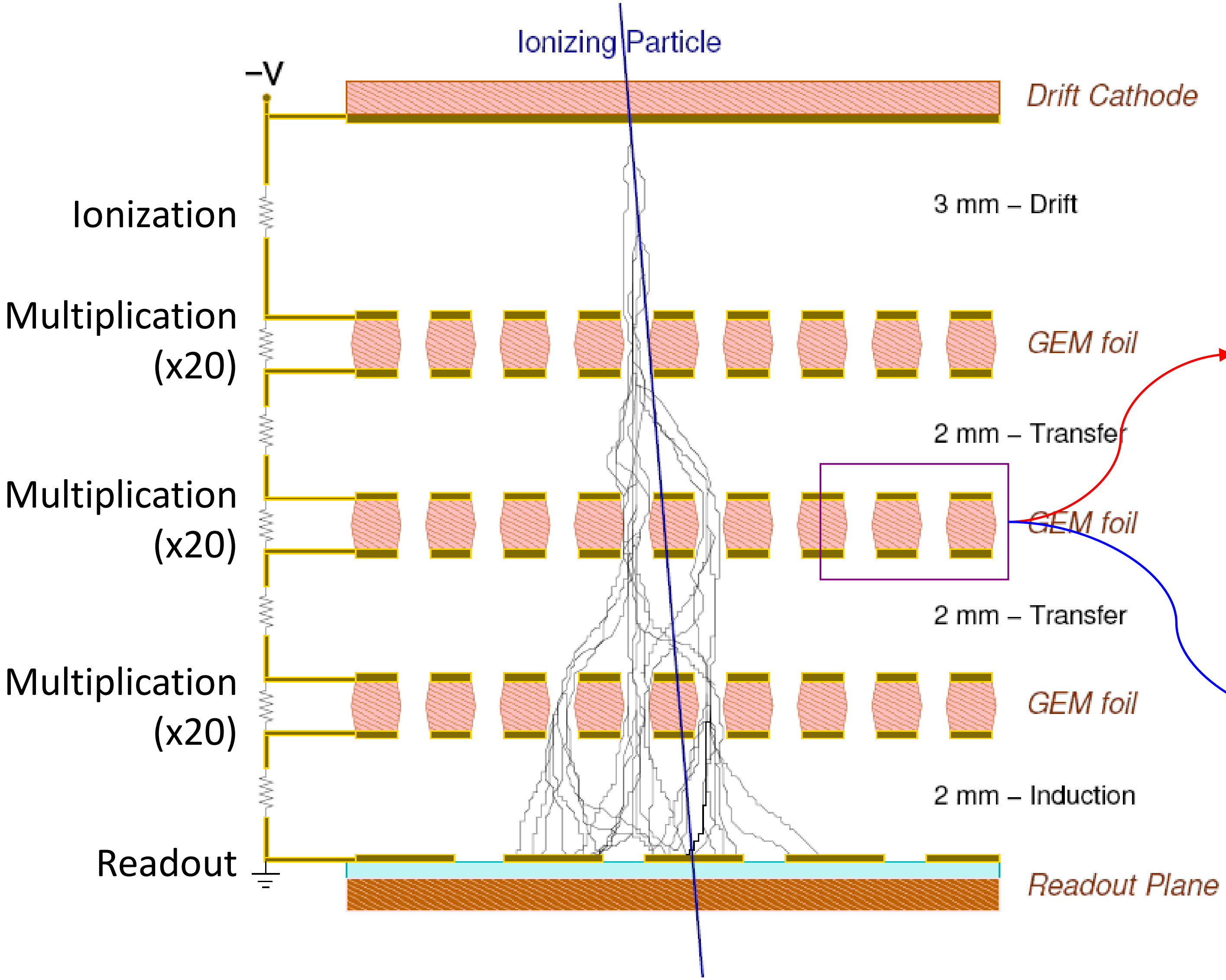
System Requirements	Tracking Technology		
	Drift	**MPGD**	Silicon
High Rate (up to): **1 MHz/cm^2**	NO	**MHz/mm^2**	**MHz/mm^2**
Resolution: **200 μm**	Achievable	**50 μm**	30 μm
Large Area: Single chamber up to 0.5 m^2 total 23 m^2	YES	**Doable**	Very Expensive

MPGD → **GEM**, **μMs**

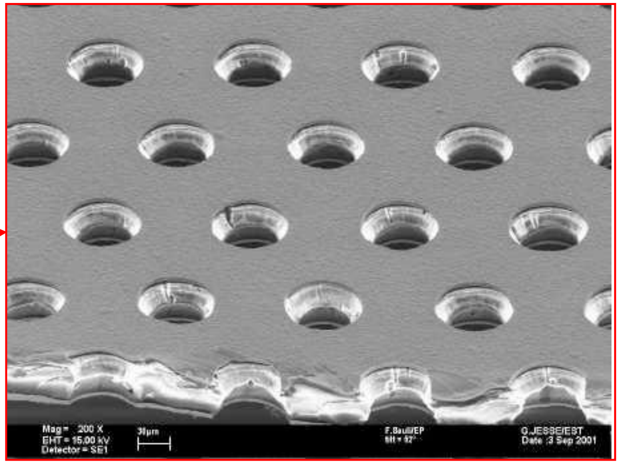
Flexibility in readout geometry and lower spark rate → **GEM**

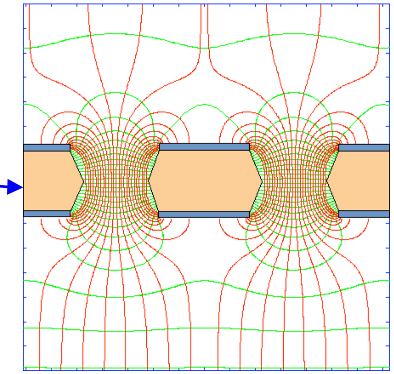
New recent development in resistive μM and GEM + μM to improve spark rate

GEM working principle



GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch





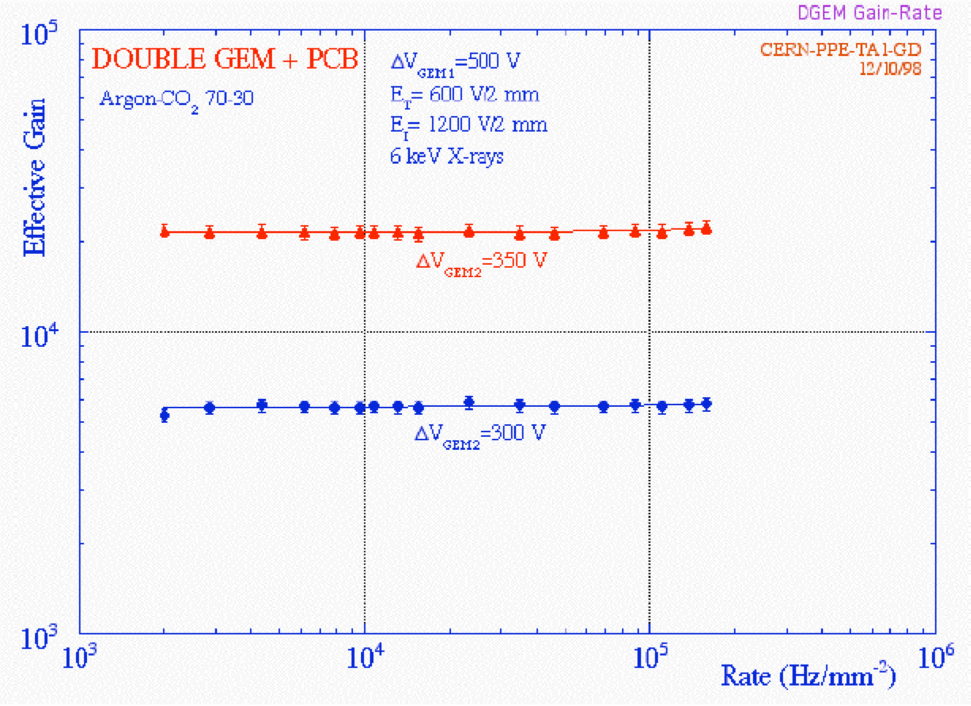
Strong electrostatic field in the GEM holes

Recent technology: F. Sauli, Nucl. Instrum. Methods A386(1997)531

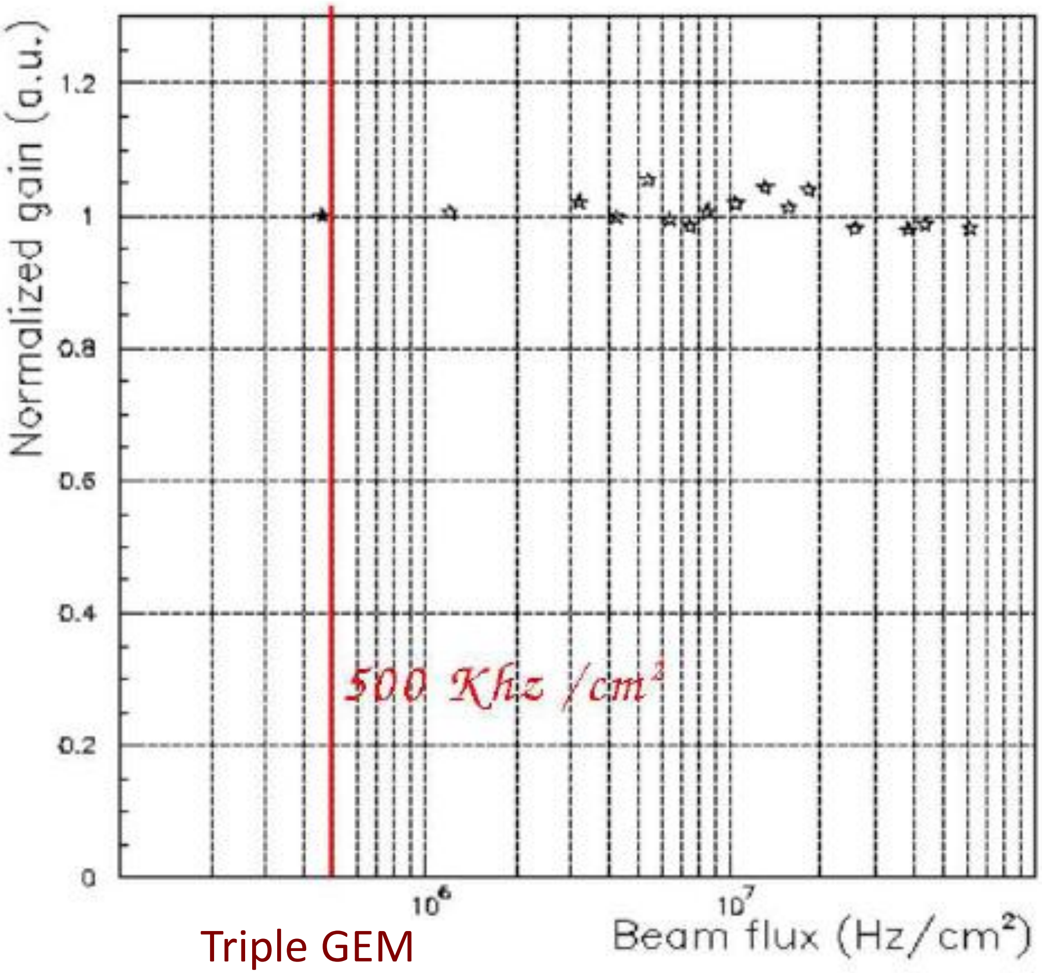
Readout independent from ionization and multiplication stages

GEM / Rate capability

- Can operate in rather high hit rate

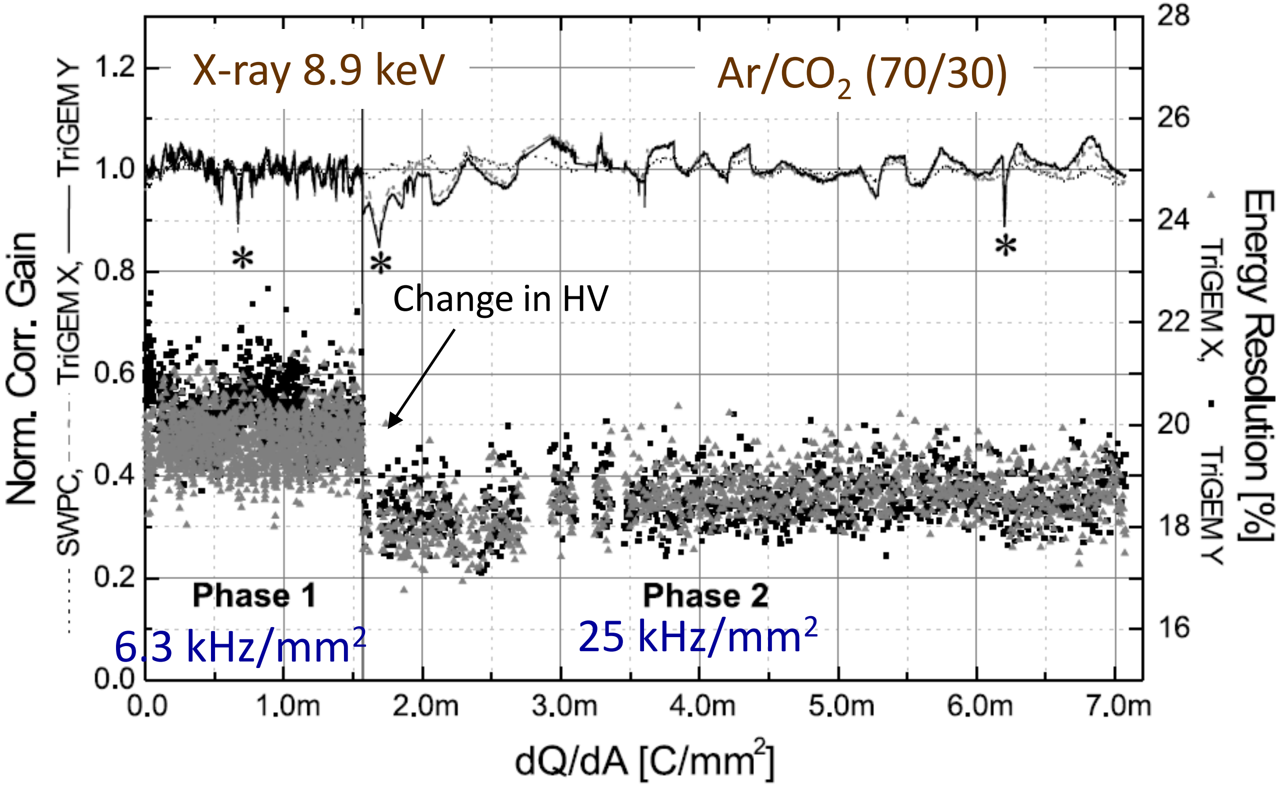


Ar/CO$_2$/CF$_4$ (60/20/20)



Triple GEM
Poli Lener, PhD Thesis - Rome 2005

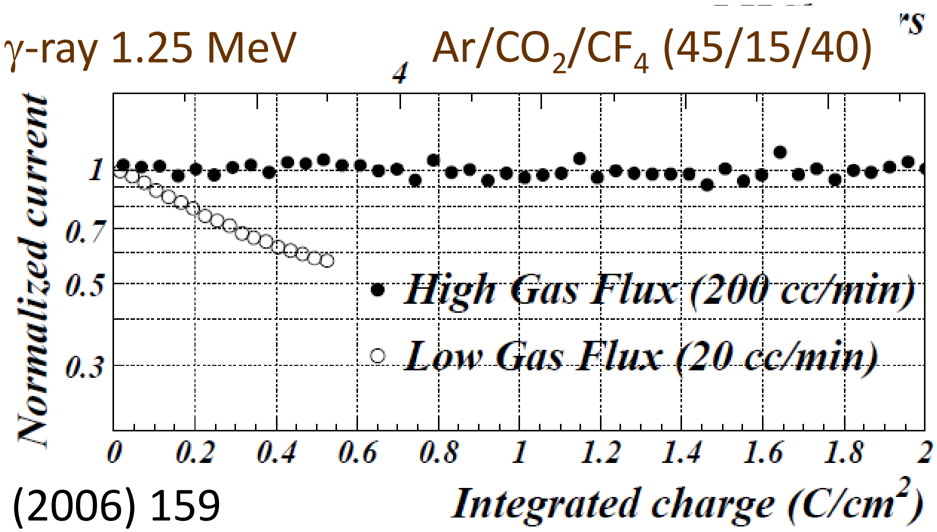
Aging in COMPASS and LHCb



Altunbas et al.
NIMA 515 (2003) 249

Rather robust to aging.
Gas type and flux is important.
Use of not-outgassing epoxy.

Typical collected charge expected at the level of 0.5 mC/mm2/y for at L~10^{38}



Alfonsi et al.
Nucl. Phys. B 150 (2006) 159

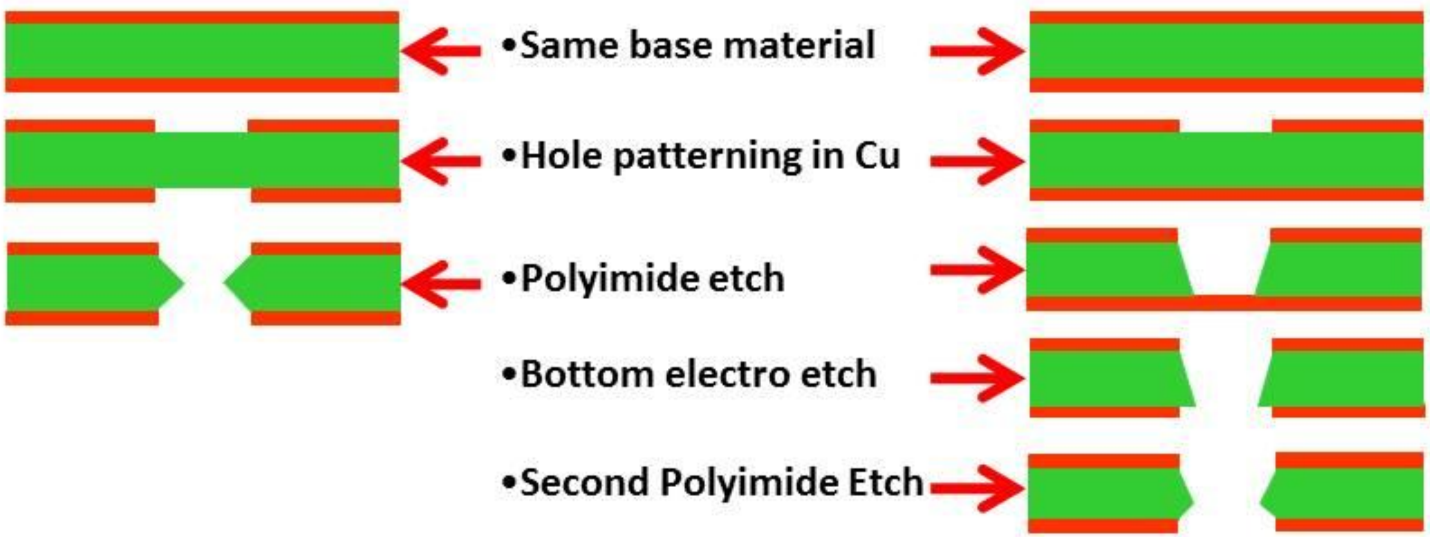
Large Size GEM

GEM double mask Vs GEM single Mask

- Base material : Polyimide 50um + 5um on both sides
- Polyimide : Apical NP from company Kaneka (Japan)
- Supplier of the copper clad material : Nippon Mining (Japan)

Original method
- Double mask

Last few years
- Single mask



- Limited to 40cm x 40cm due to
  - Mask precision and alignment

- Limited to 2m x 60cm due to
  - Base material
  - Equipment

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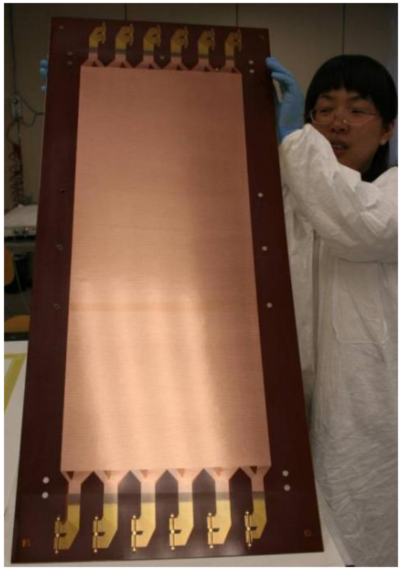
Large size available in recent years!

CMS Upgrade Prototype (42cm x 990 cm)



KLOE Inner Tracker (40 cm x 700 cm)

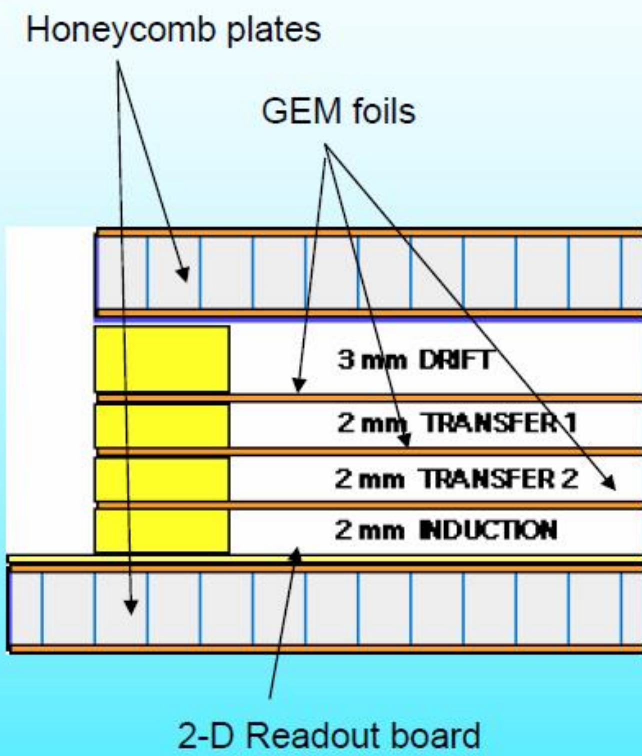
The «Reference» GEM

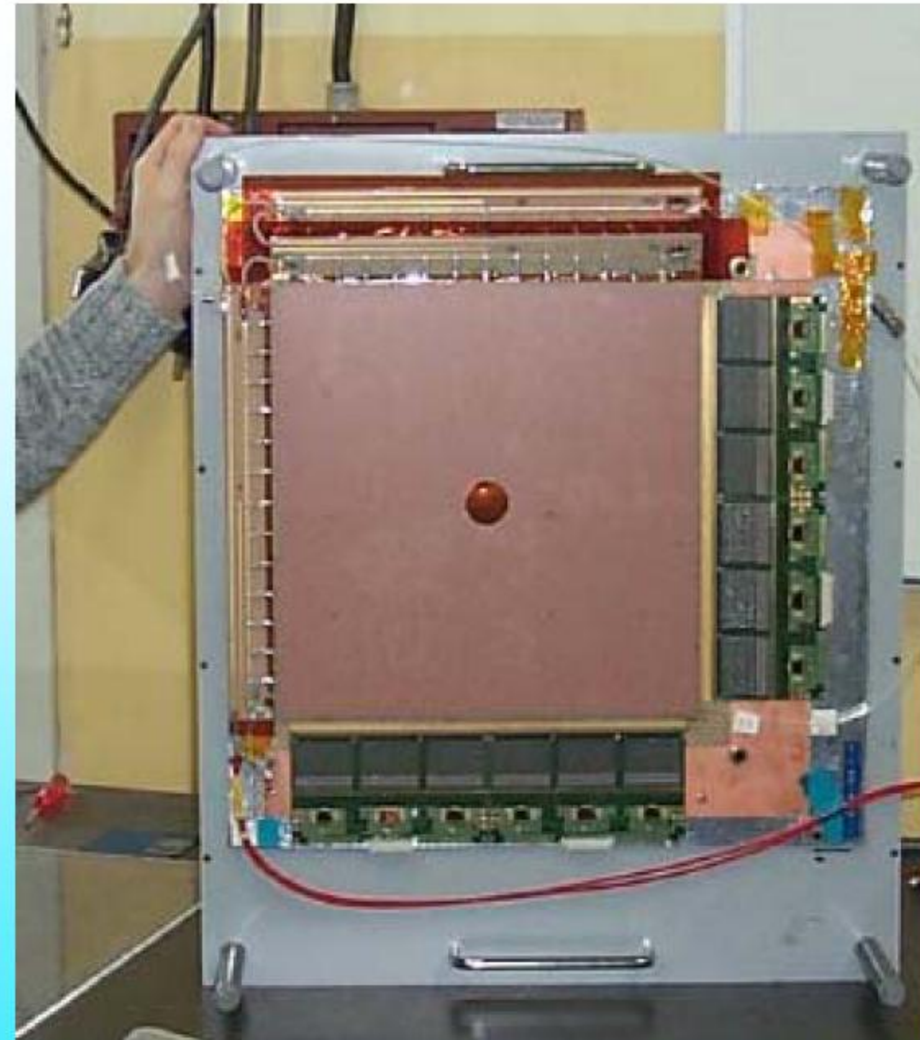
From: F. Sauli, Napoli - 2005

COMPASS T-GEM — *Fabio SAULI*

COMPASS Triple-GEM detectors

Light all-glued construction:
$0.7\%\ X_0$ in active area

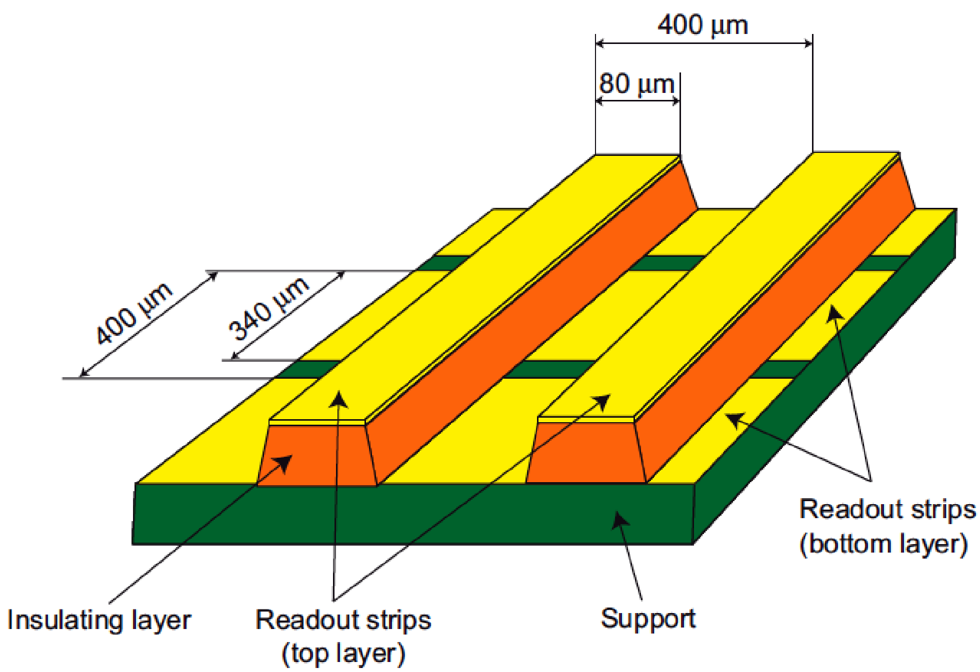


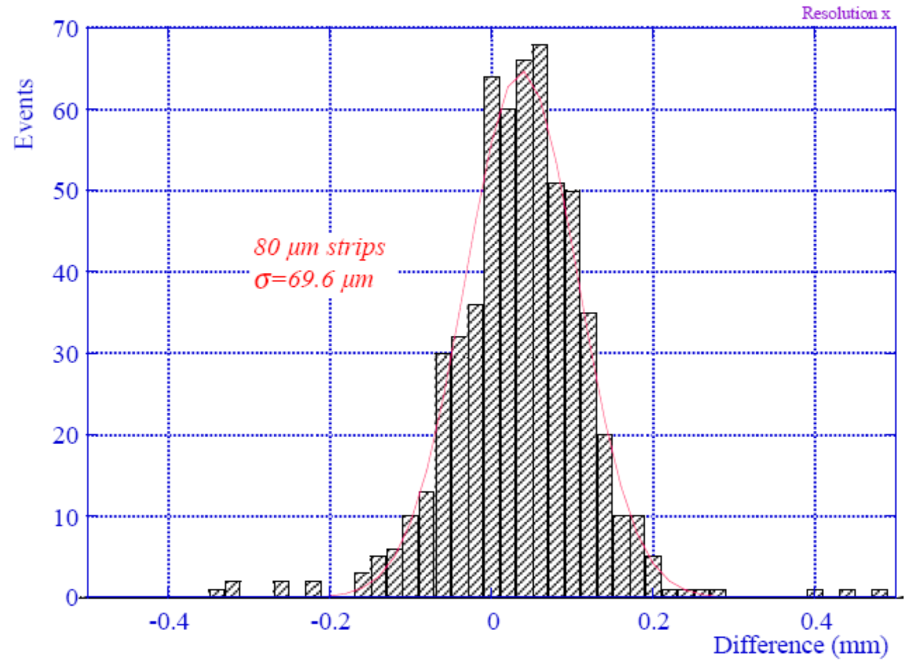


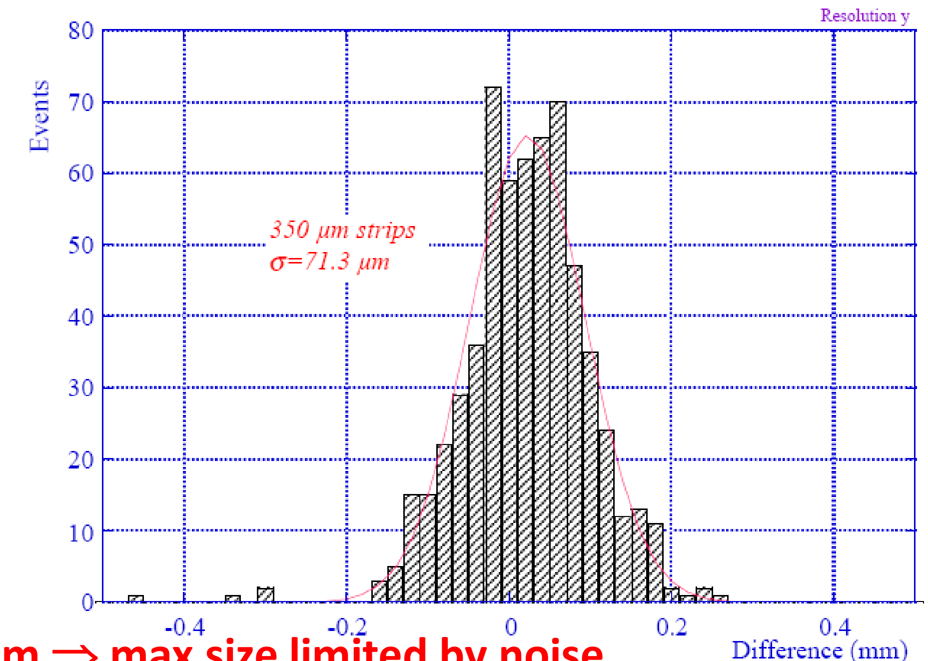
C. Altumbas et al, Nucl. Instr. Methods A490(2002)177

SLIDE 11

Spatial Resolution in COMPASS GEM: 70 μm







COMPASS readout plane ($33x33\ cm^2$) and results

C. Altunbas et al.
NIMA 490 (2002) 177

70 μm resolution achieved by strips centroid

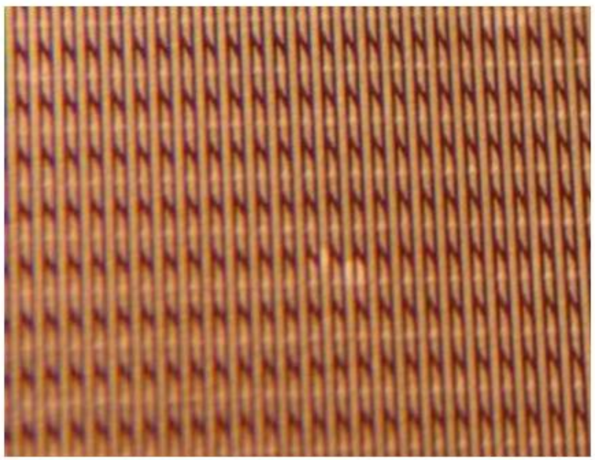
⇒ **Analog readout required**

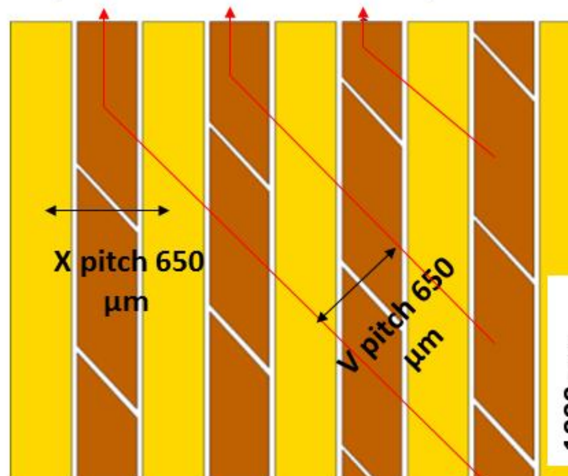
Strip Capacitance ~1 pF/cm ⇒ max length < 100 cm ⇒ max size limited by noise

Alternative 2D readout, the KLOE solution

(2) XV readout and magnetic field

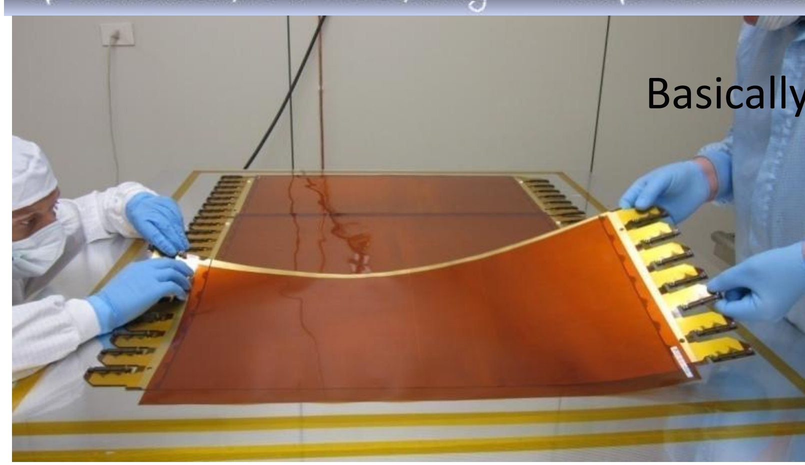
A new readout was drawn to fit the cylindrical shape of the IT anodes: a doubl
layer circuit with an X-V pattern realized with strips (X) and pads (V) etched o
the same kapton layer. Pads are connected by vias to form the V-strips.





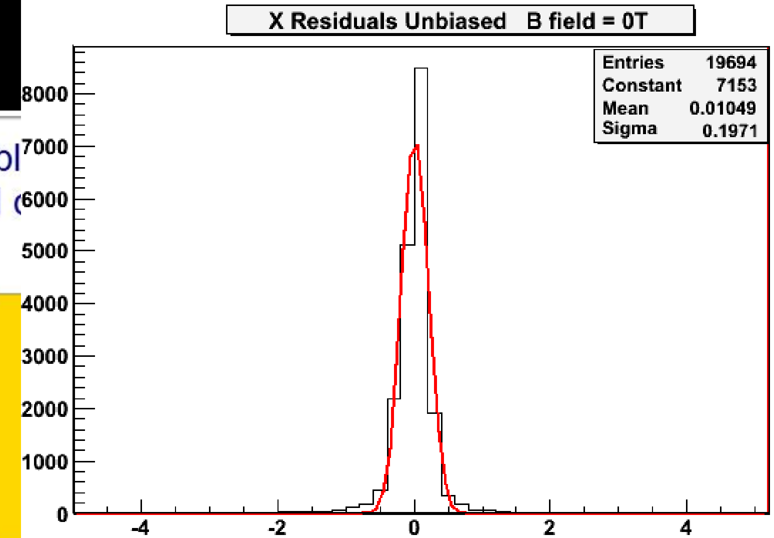
The new readout, mounted on small planar GEMs, has been tested in magnetic field on a test beam at CERN.

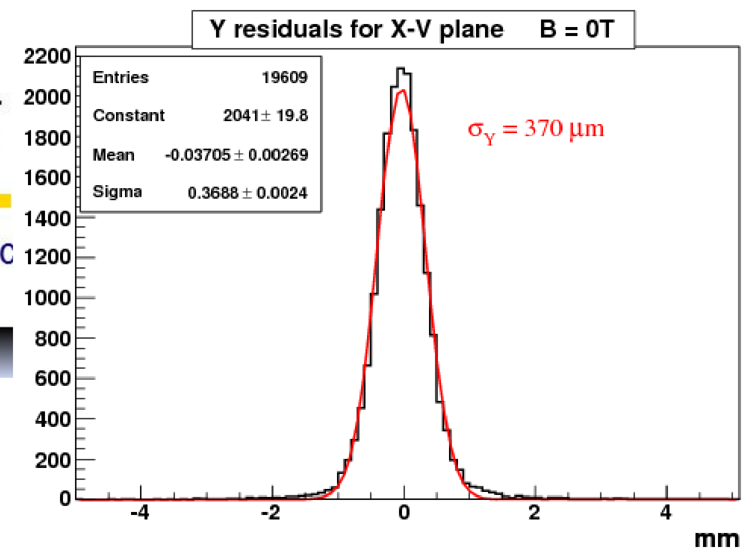
G. Bencivenni, LNF-INFN, Italy MPGD-2011/8/31 11



Basically, any direction possible

From Bencivenni / MPGD-2011 / Kobe





Pitch limited by technology and cost

Smaller pitch used in Olympus/DESY, on GEM chambers of 10x10 cm2

Electronics

Name	Exp	Det	#ch	Shaper (ns)	Noise	Range (fC)	Pol.	ADC	f (MHz)	P/ch. (mW)	Feat.	Tech	Rad hard
APV25	CMS	Si strip	128	50	270+38e/pF	20	both	A	40	2.7	PD, PR	0.25 CMOS	10
AFTER	T2K	TPC	72	100-2000 s-gauss	(350-1800) + (22-1.8)e/pF	19	both	A	1-50 (100)	7.5	VG,VS	0.35 CMOS	no
MSGCROC	DETNI	Gas strip	32	T: 25 E: 85	2000e @ 40pF	800	both	A,1	2ns TDC		VG, ZS	0.35 CMOS	no
Beetle	LHCb		128	25	500+50e/pF	17.5	both	A/1	40	5.2	F-OR	0.25 CMOS	40
VFAT	TOTEM		128	22	650+50e/pF	18.5 (cal)	both	1	40	4.47	F-OR	0.25 CMOS	50
NINO	ALICE	TPC	8	1	1900+165/pF	2000 th<100	both	1	async	30	BR	0.25 CMOS	no
CARIOCA	LHCb	MWPC	8	<15 @ 220pF	2000+40e/pF	250	both	1	async	46	BR	0.25 CMOS	20
PASA+ ALTRO	ALICE TPC	TPC	16	190_{fwhm} s-gauss	570e @20 pF	160	both	10	20	< 40	BC, TC, ZS	0.35,0.25 CMOS	
SVX4	CDF, D0	Si strip	128	100-360	410+45e/pF	60fC	neg	8	106 (212)	2	ZS	0.25 CMOS	20
SPIROC	ILC, T2K	SiPM	36	A:25-175 T: 10	A: 1/11pe; T:1/24pe	2000 pe	neg	8-12	100ps TDC	0.025 *pulse*	dual-gain	0.35 SiGe	no

Legend: PD = peak detection, PR = pile-up rejection, VG = variable gain, VS = variable shaping, F-OR = fast-OR, BR = baseline restorer, BC = baseline correction, TC = tail correction, DC = data compression, ZS = zero suppression

Main Requiremets:

1. Radiation Hard
2. Analog Output
3. Time information
4. Reasonable speed
5. High Density

No optimal chip exists

Several chips under development

Most addressed in current activities is the APV25

Sorin Martoiu / 4th RD51 meeting / CERN / 2009

MPGD Projects similar to SOLID

(MPGD = Micro Pattern Gas Detector)

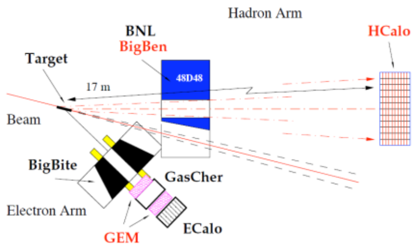
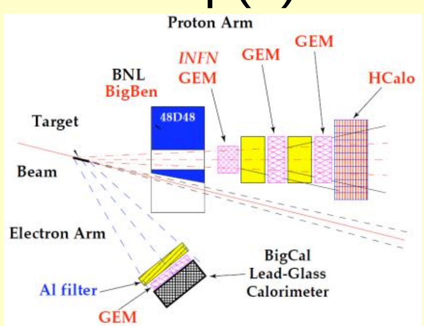
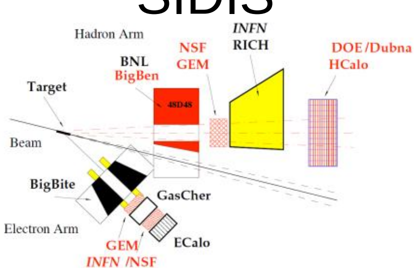
- KLOE (Moderately large GEM)
- JLab/Hall A (Moderately large GEM)
- CMS Upgrade (Large GEM)
- Atlas Small Wheel Upgrade (Resistive Micromegas)

LHC projects push technology development and consolidation of the production quality

Technology transfer to industry required for large production !

JLab/HallA GEM Tracker for 12 GeV physics

Some challenging experiments in Hall A

Experiments	Luminosity $(s \cdot cm^2)^{-1}$	Tracking Area (cm^2)	Resolution		
			Angular (mrad)	Vertex (mm)	Momentum (%)
GMn - GEn 	up to $7 \cdot 10^{37}$	40x150 and 50x200	< 1	<2	0.5%
GEp(5) 	**up to $8 \cdot 10^{38}$**	40x120, 50x200 and 80x300	<0.7 ~1.5	~ 1	0.5%
SIDIS 	up to $2 \cdot 10^{37}$	40x120, 40x150 and 50x200	~ 0.5	~1	<1%

Most demanding

High Rates

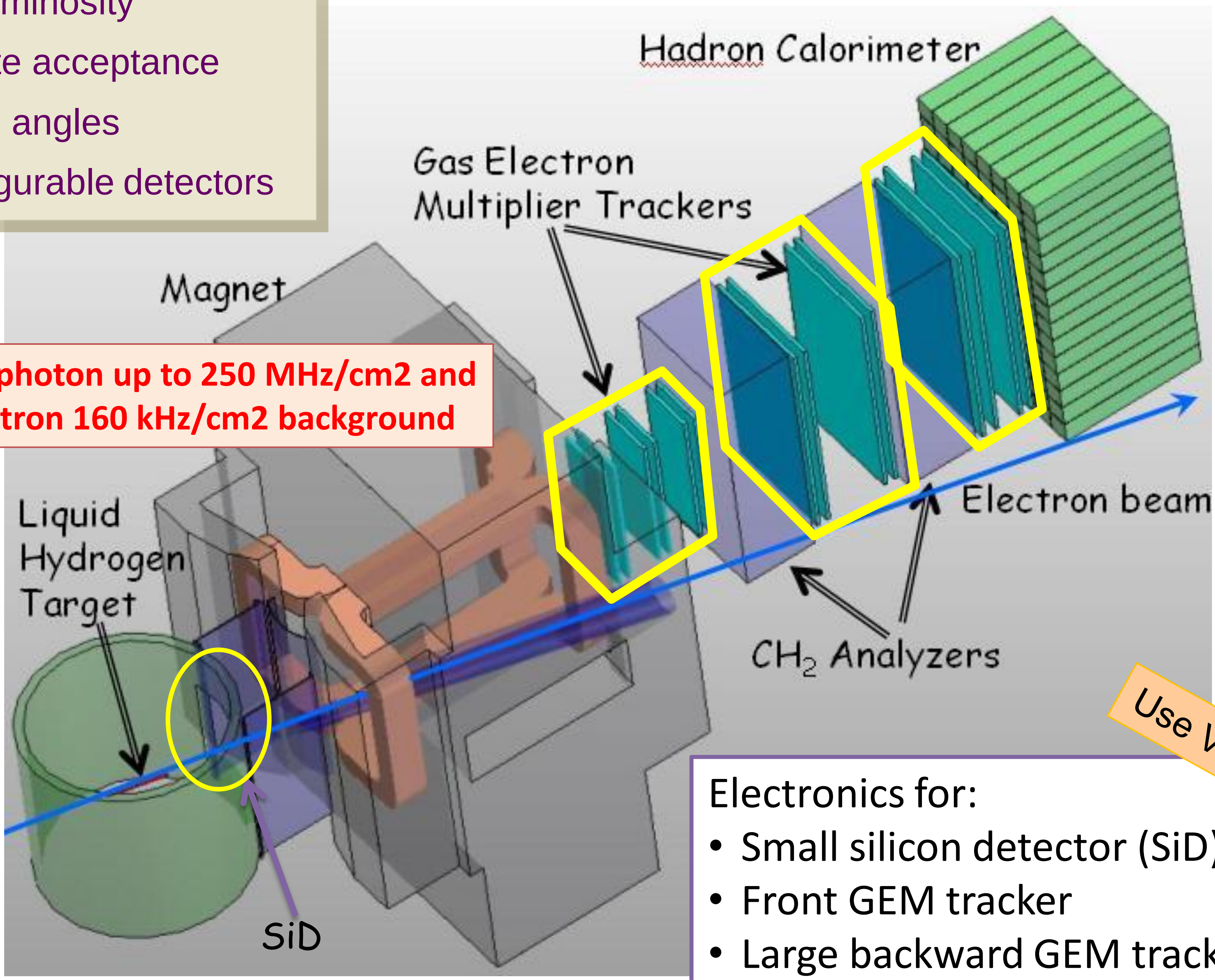
Large Area

Down to ~ 70 μm spatial resolution

Maximum reusability: same trackers in different experimental configuration

SuperBigbite Spectrometer in Hall A

- Large luminosity
- Moderate acceptance
- Forward angles
- Reconfigurable detectors



High photon up to 250 MHz/cm2 and electron 160 kHz/cm2 background

Use VME64x

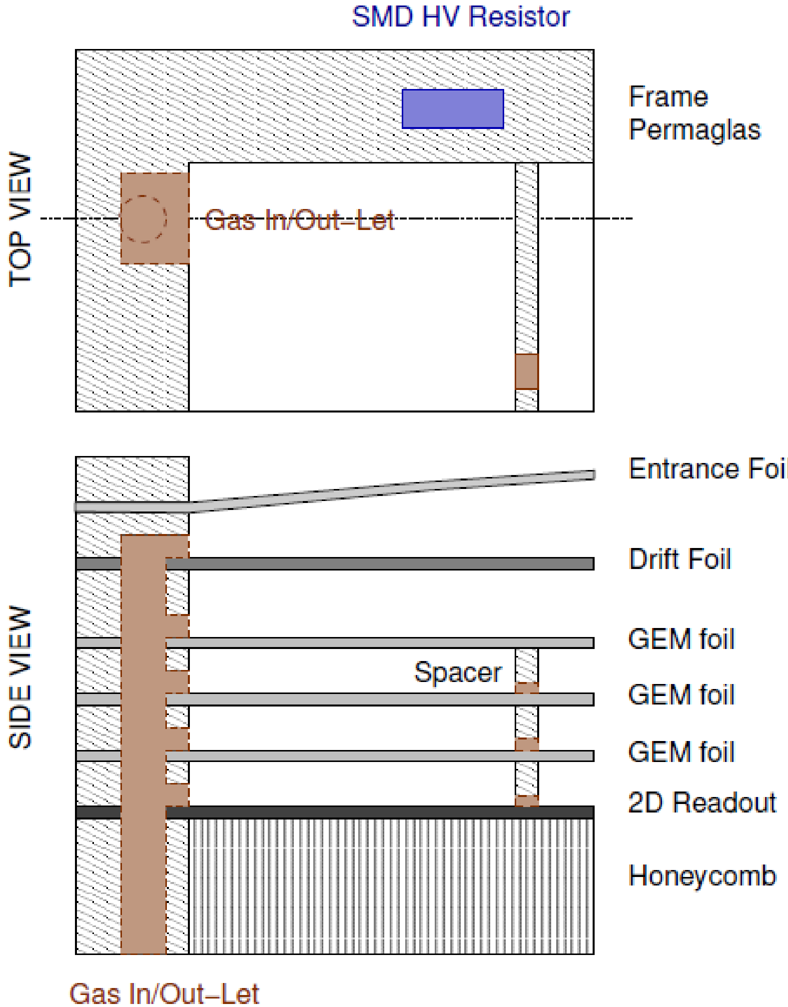
Electronics for:
- Small silicon detector (SiD)
- Front GEM tracker
- Large backward GEM trackers

⇨ **>100k channels**

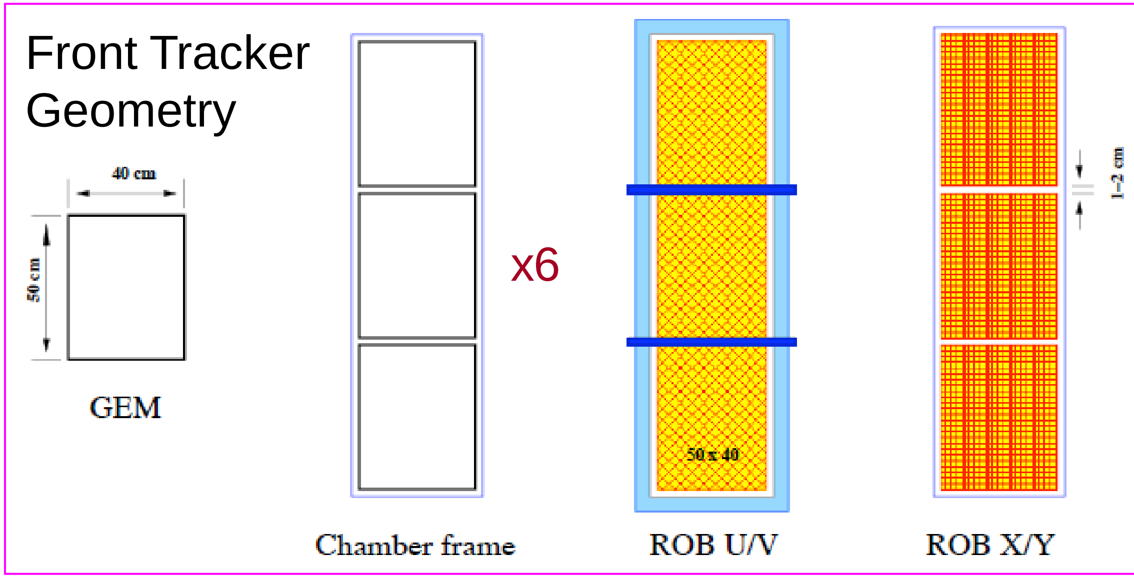
Tracker approach: 40x50 cm^2 Module

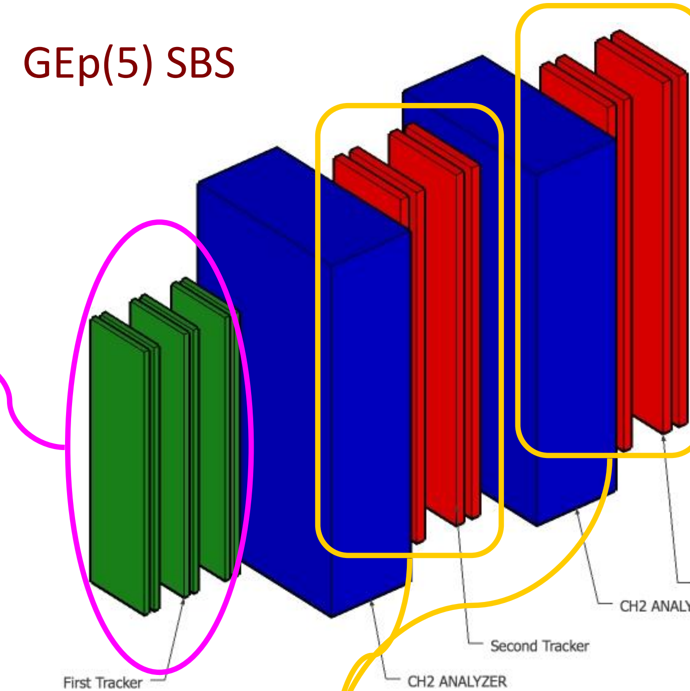
Use the same "basic" module for all trackers types

- Size: 40x50 cm^2 active area
- 8 mm thin frame
- 3 x GEM foils (using single mask tech.)
- 2D strip readout (a la COMPASS) - 0.4 mm pitch
- X/X0 = 0.54%
- APV25 readout chip

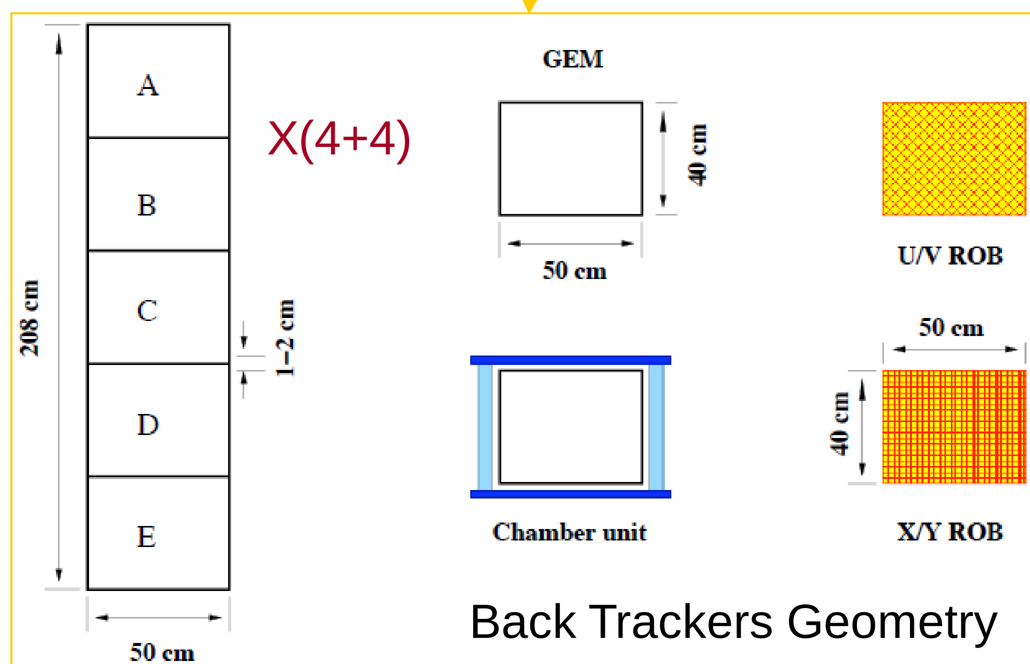


Tracker Chambers configuration

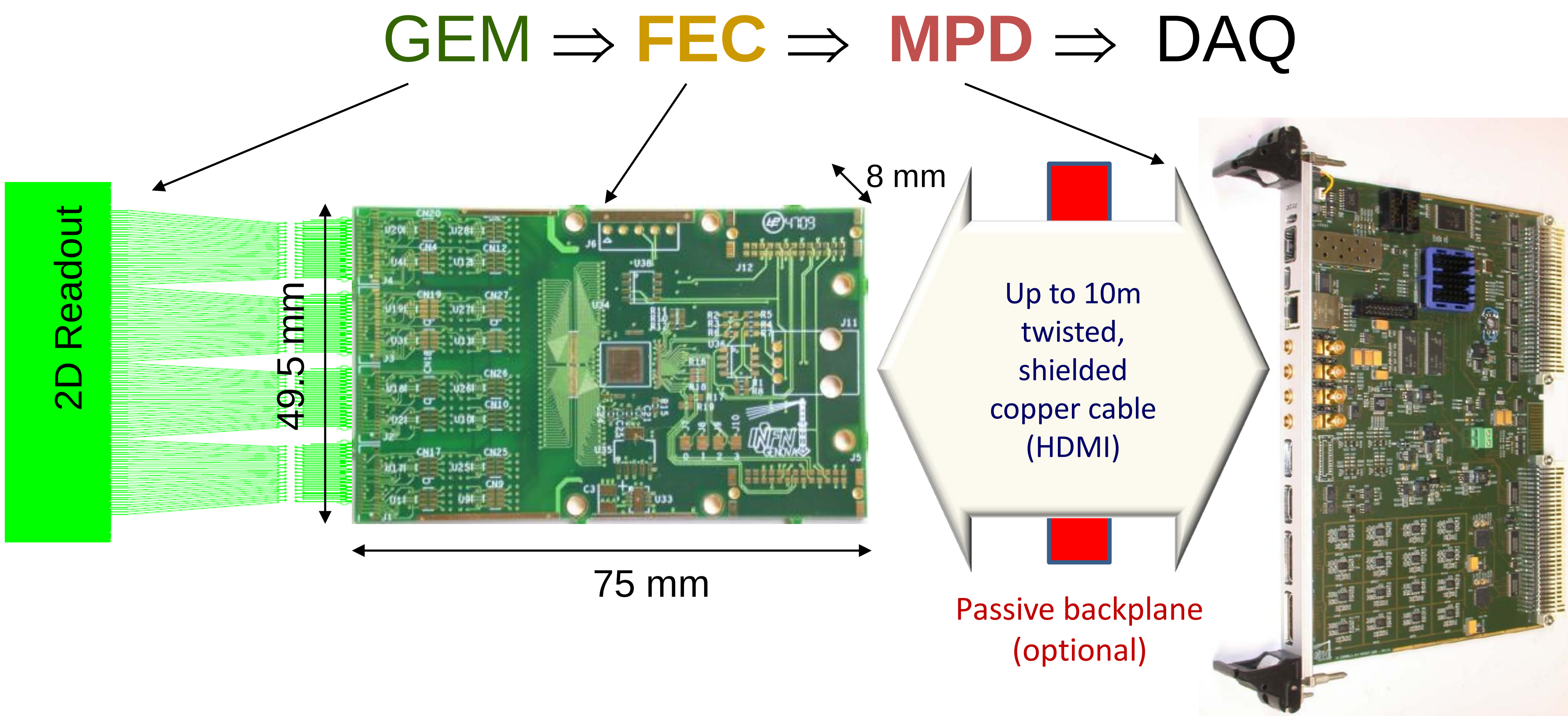




- Modules are composed to form larger chambers with different sizes
- **Electronics along the borders and behind the frame (at 90°) – cyan and blue in drawing**
- **Carbon fiber support frame around the chamber (cyan in drawing); dedicated to each chamber configuration**



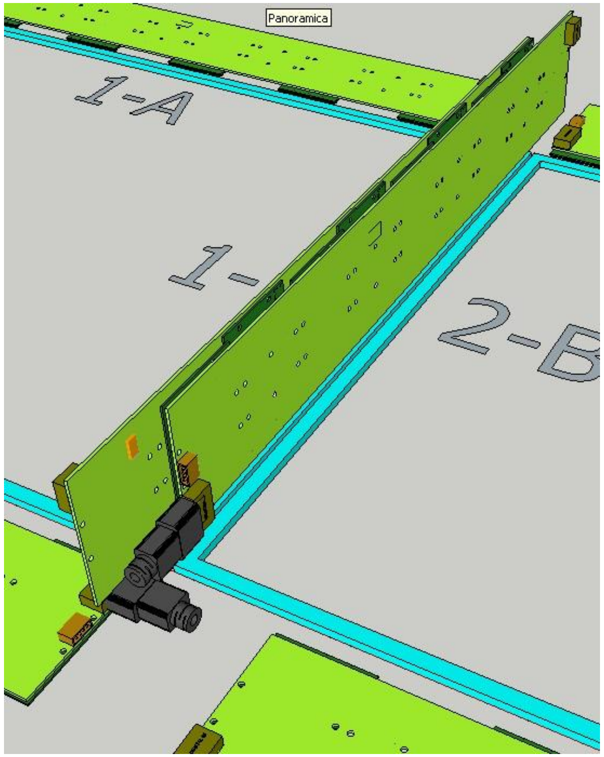
Electronics Components

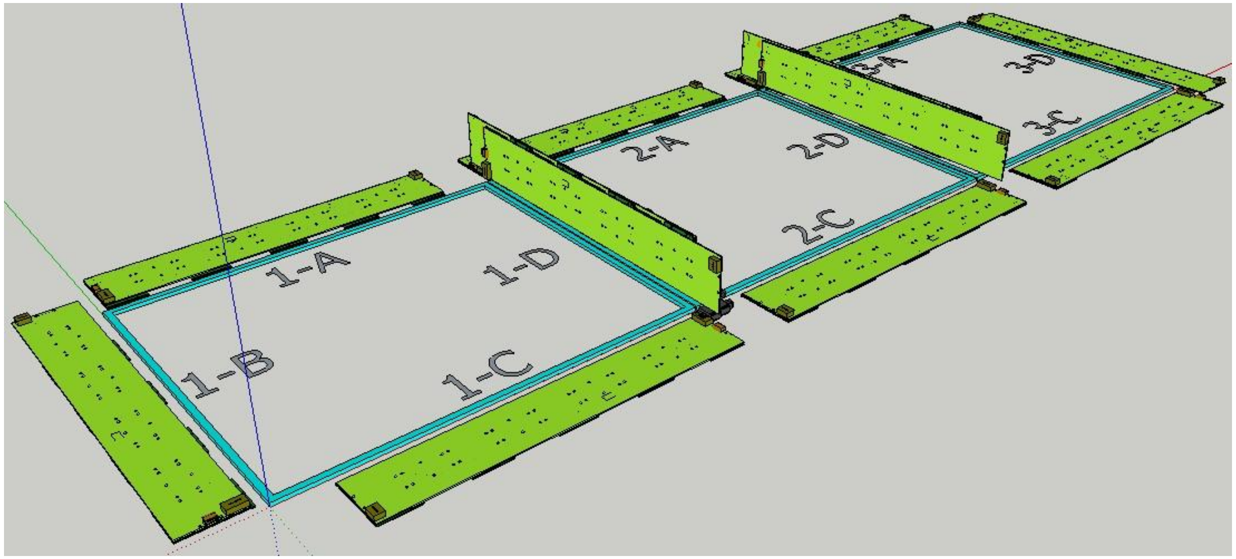


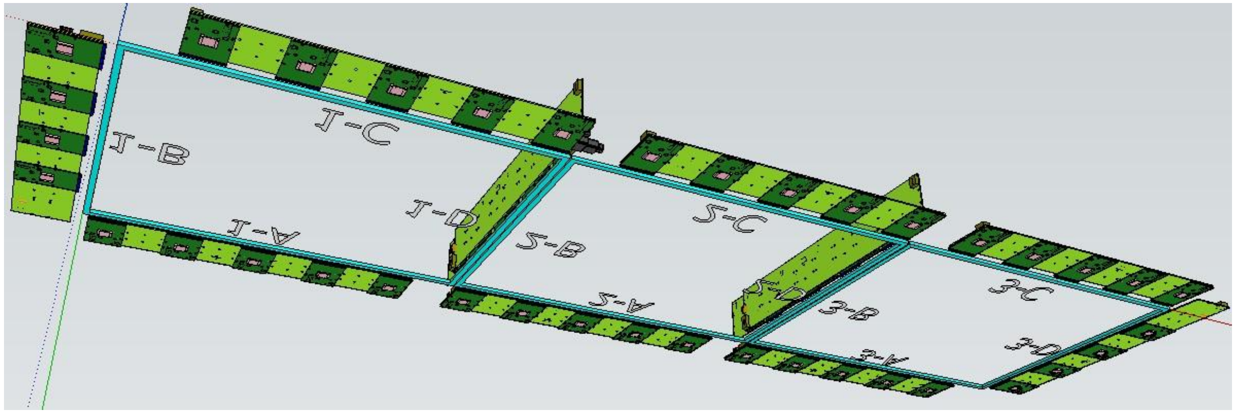
Main features:

- Use analog readout APV25 chips (analog and time information)
- 2 “active” components: Front-End card and VME64x custom module
- Copper cables between front-end and VME
- Optional backplane (user designed) acting as signal bus, electrical shielding, GND distributor and mechanical support

Electronics layout of one chamber



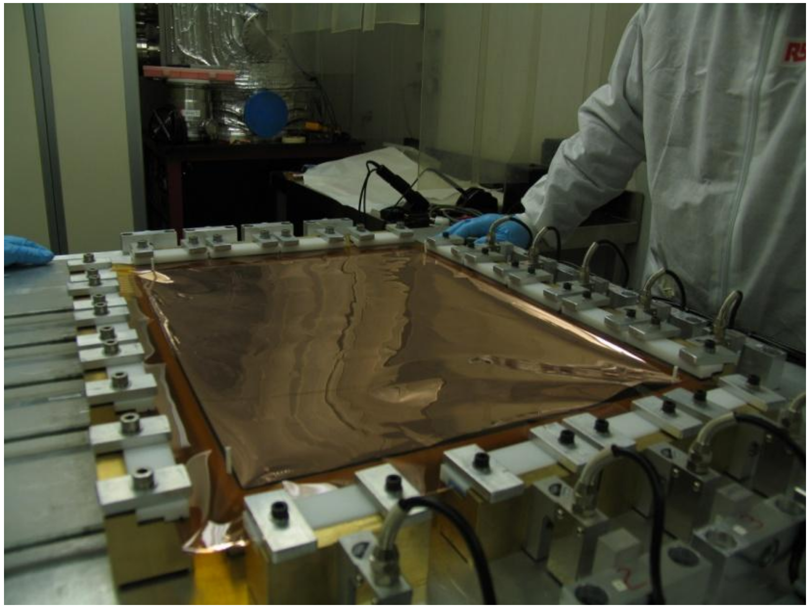




FE cards are connected by a passive backplane (with hard rad voltage regulators); backplane acts as a good GND connection for the cards

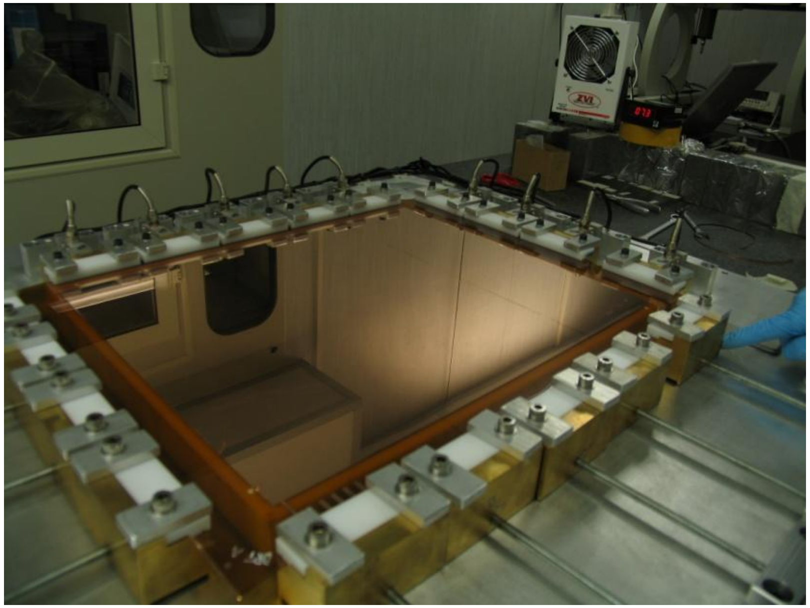
Front-end cards are electromagnetically shielded by backplane and external frame (with thin conductive tape)

Assembling the first 40x50 cm2 module



Stretching

Stretcher design from LNF / Bencivenni et al.

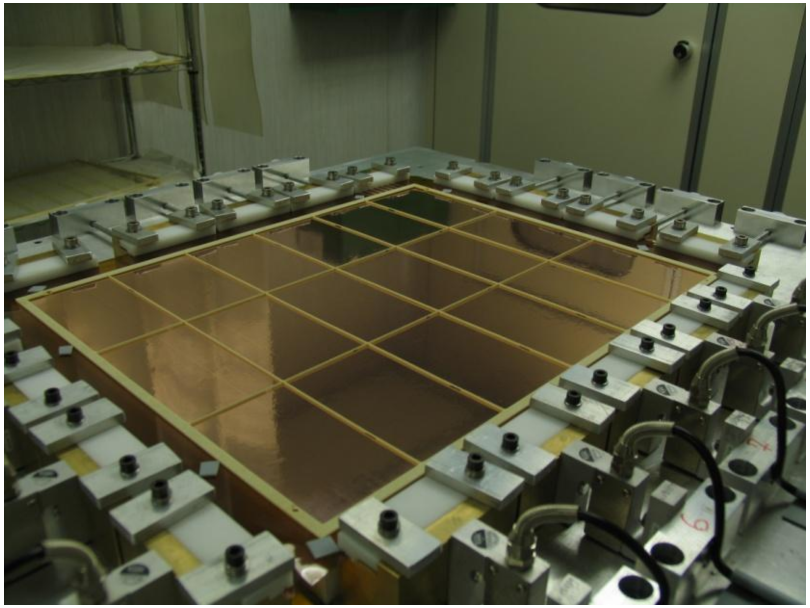


Use stretching and spacers to keep foil flat

Foil Tension: **T = 2 kg/cm**
Spacer Sector: **S = 170 cm2**
Expected maximum pressure on foil **P ~ 10 N/m2**

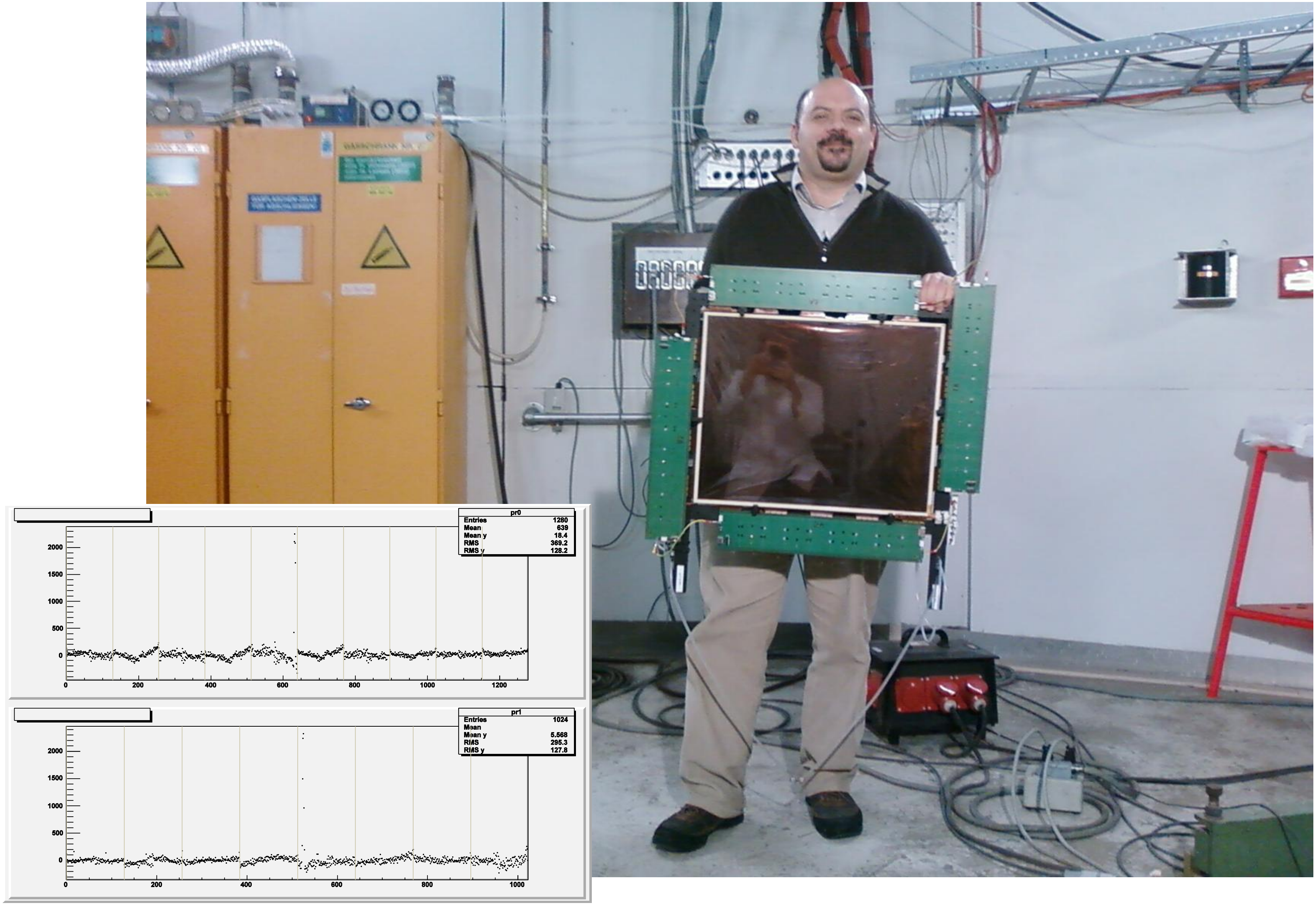
⇓

Maximum foil deformation:
u ~ 0.0074 * P * S / T = **6.4 μm**



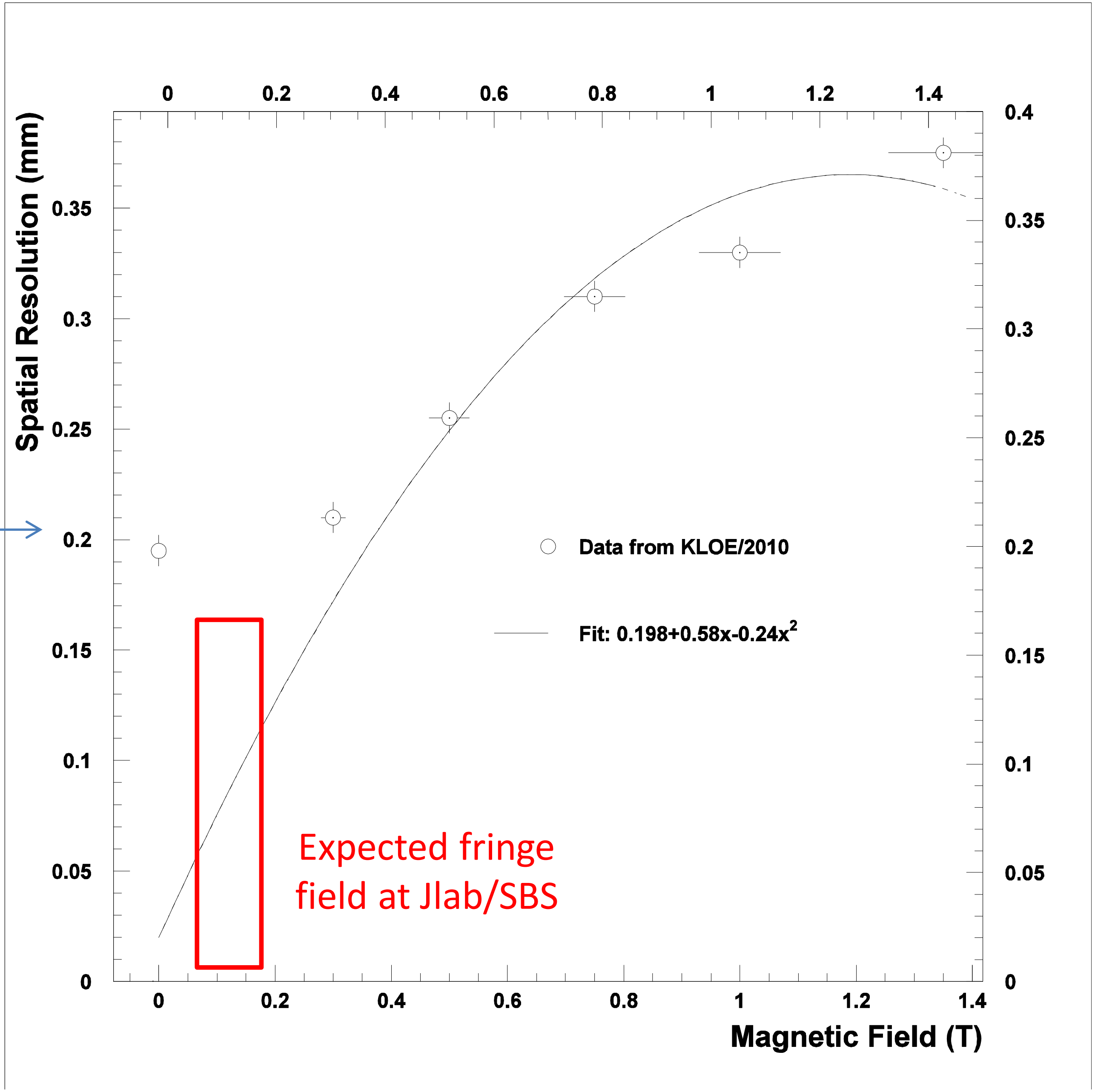
Gluing the next frame with spacers

Beam test @ DESY (EUDET support)



Magnetic field / Extrapolation from KLOE Data

Limit due to readout pitch

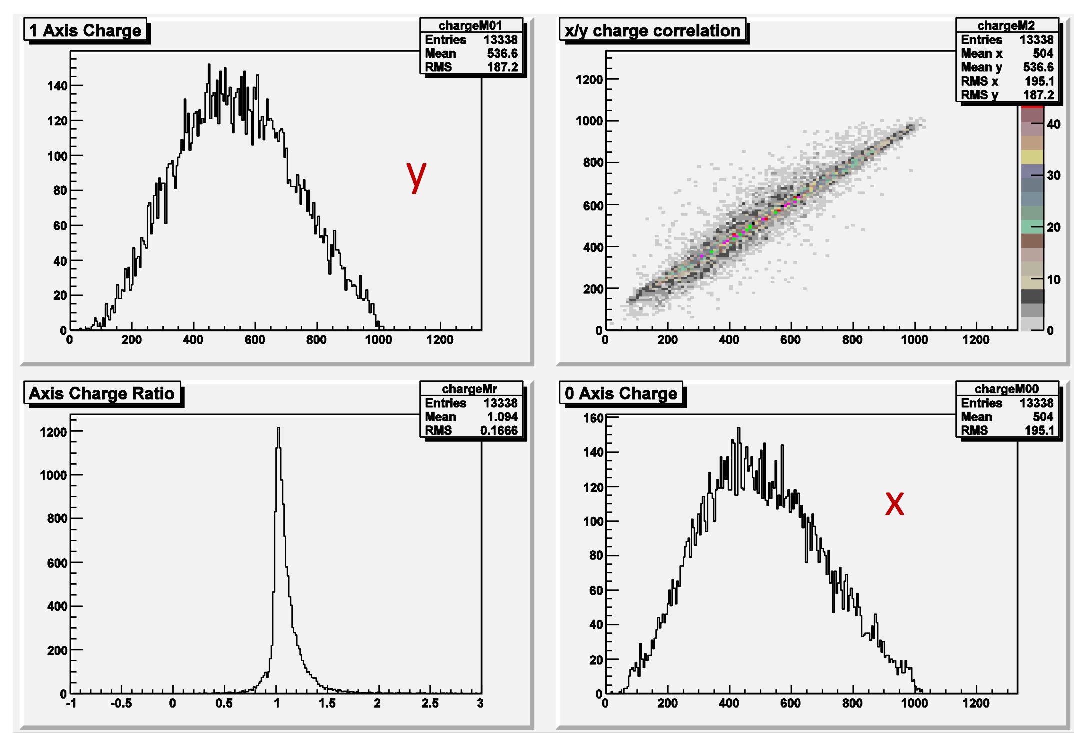


From Hits to Track

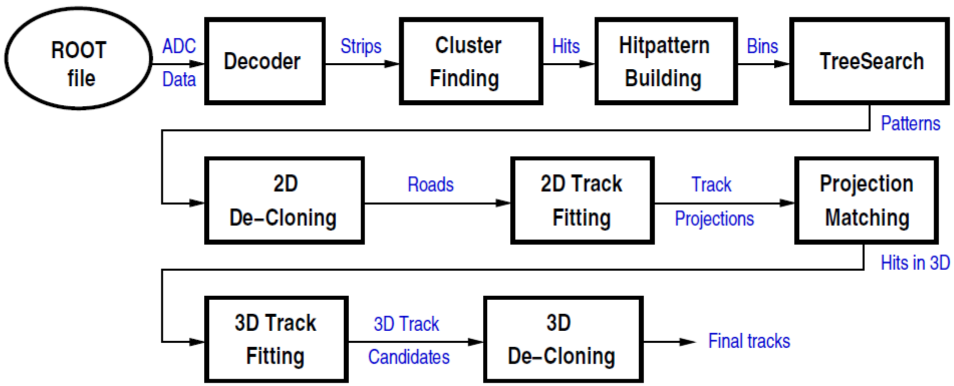
- Tracking in high luminosity is not trivial
- Background hits shall be identified and minimized
  - Time correlation with trigger

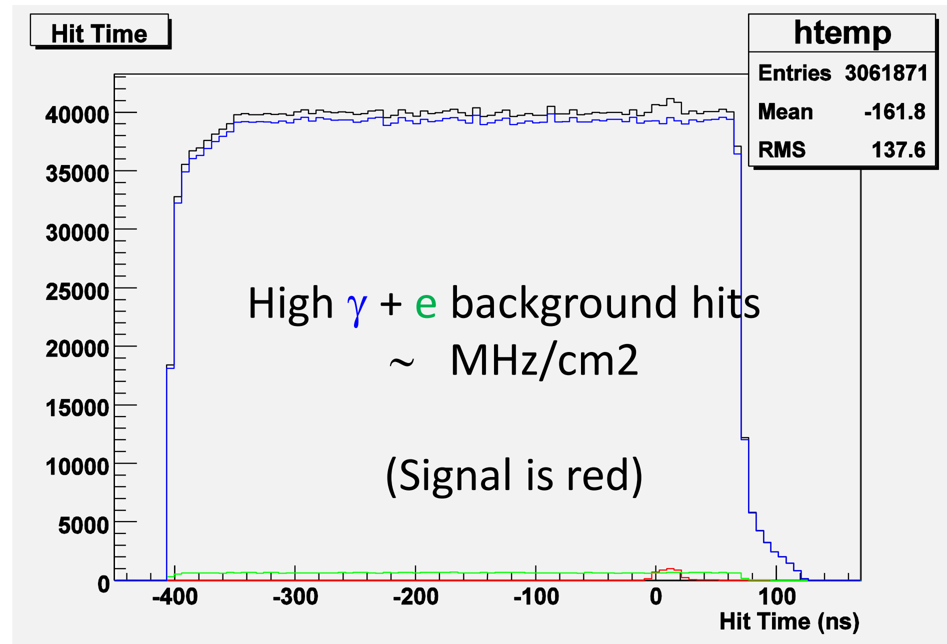
X-strip hit distribution

- Remove false (ghost) hits
  - Amplitude correlation in 2D readout plane (→)
  - x/y and u/v planes



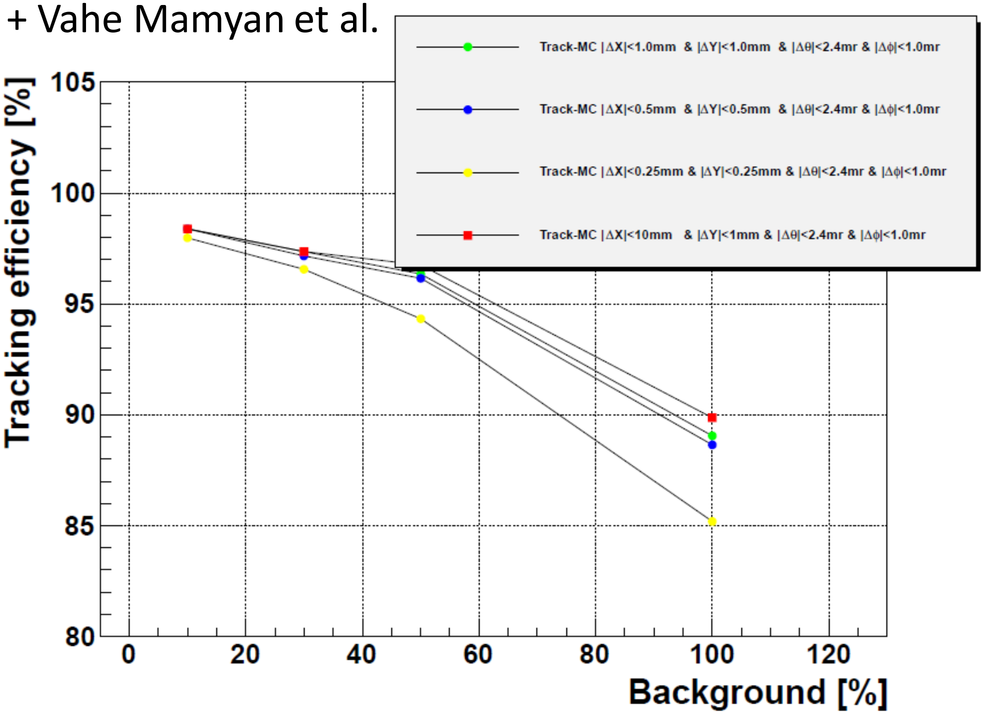
MonteCarlo + Digitazation + Tracking

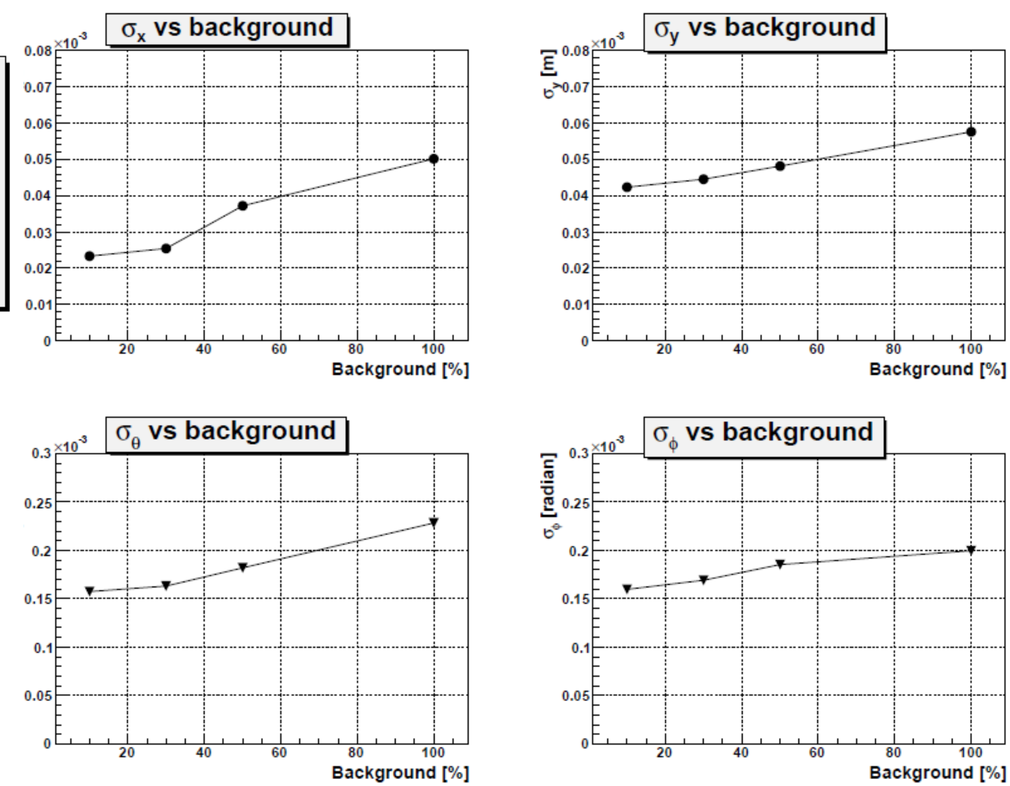




6 GEM chambers with x/y readout
Use multisamples (signal shape)
for background filtering

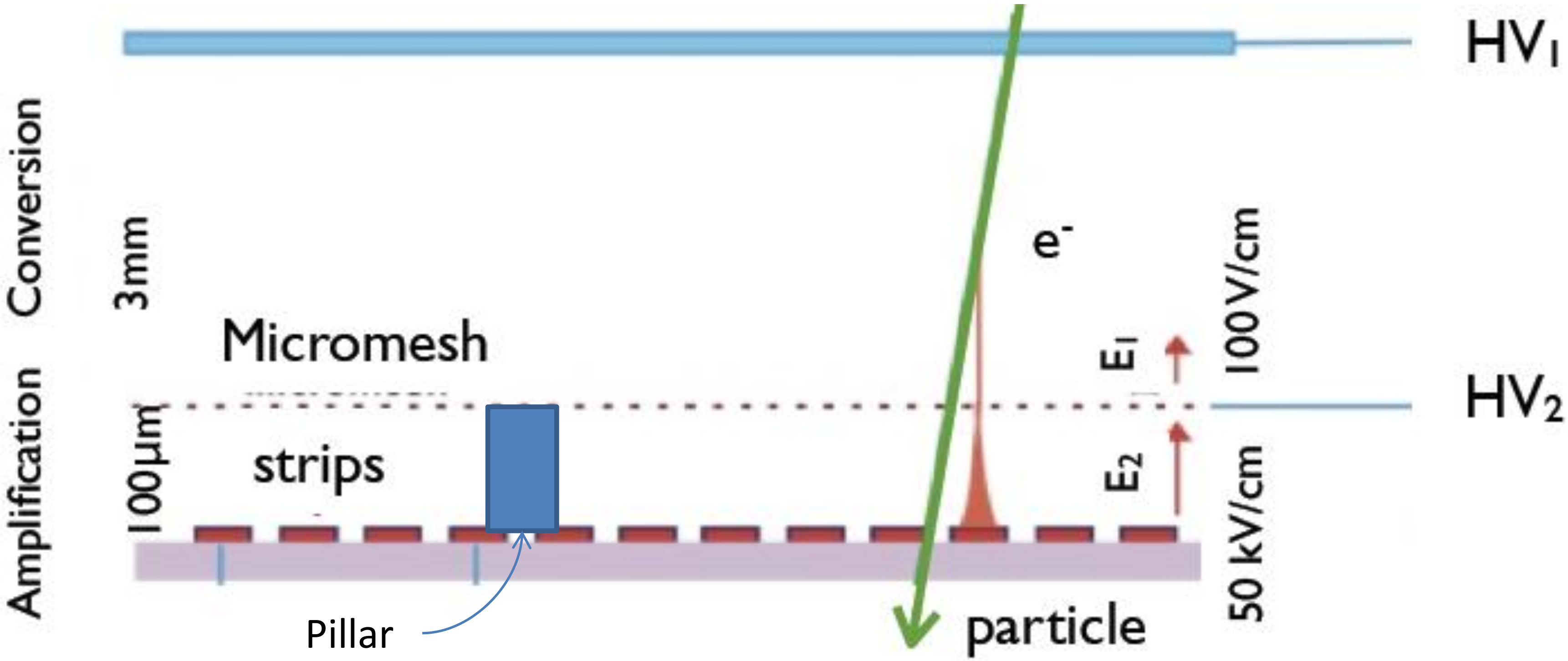
Bogdan Wojtsekhowski + Ole Hansen
+ Vahe Mamyan et al.





GEM Competitors

GEM Competitor: Micromegas



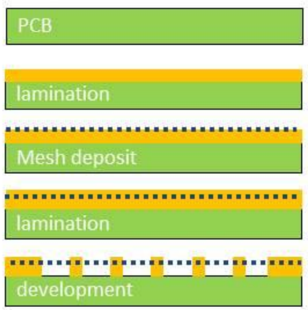
- Only two HV needed
- Multiplication similar to the 3xGEM
- Accurate spacing between mesh and strip plaenes
- Standard micromegas soffer of high discharge rate
- Latest developments use resistive material on the electrodes to reduce the energy of sparks

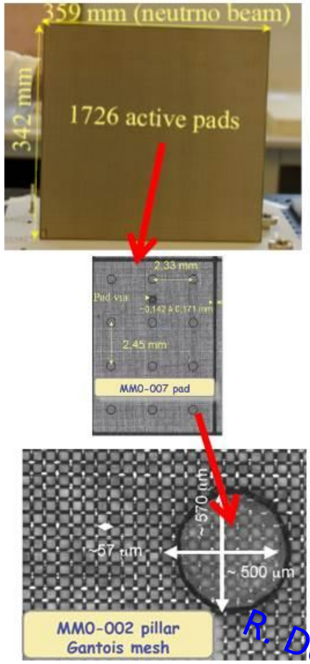
Large Area/Spark suppression/2D MicroMegas

Large Micromegas

BULK Technology
DUPONT PC 1025 coverlay
BOPP Meshes
SERITEC stretching

3 technicians involved:
Olivier Pizzirusso
Antonio Teixeira
Julien Burnens





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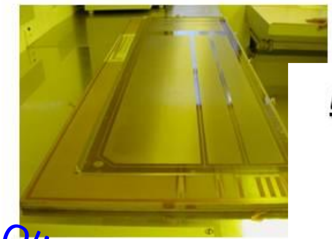
Large area

Largest size produced:
1.5m x 0.6m
Limited by equipment



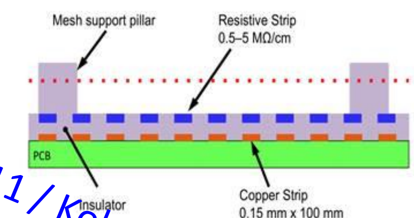
R. De Oliveira / MPGD2011 / Kobe

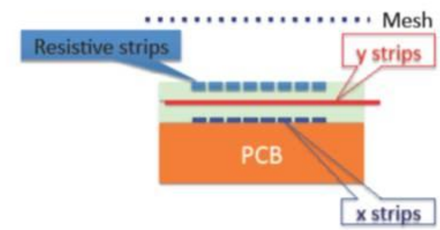
Combination of several recent technologies (mainly developed at CERN)

Resistive layers:

- Spark suppression
- Multi-dimensional readout

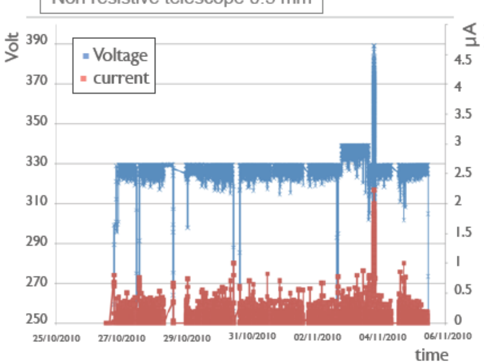
Bulk MicroMegas resistive anode and 2D readout



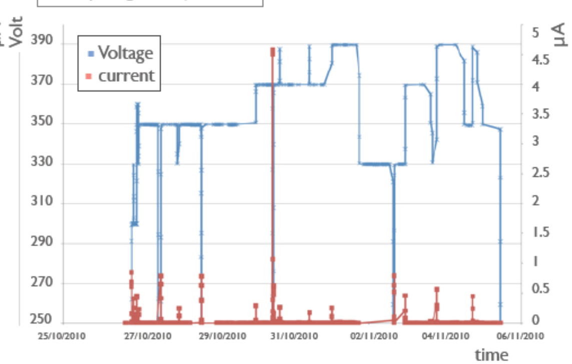


Reduced sparks

Non resistive telescope 0.5 mm



R-strip to ground, 1.0 mm

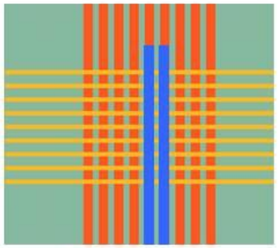


J.Manjarres-Ramos / MPGD2011 / Kobe

Development for Atlas Upgrade

We have produced :
X/Y read-out
U/V/W read-out
GEM mesh detectors
Grounded mesh detectors

(see Joerg Wotschack talk for details)



Resistive strips

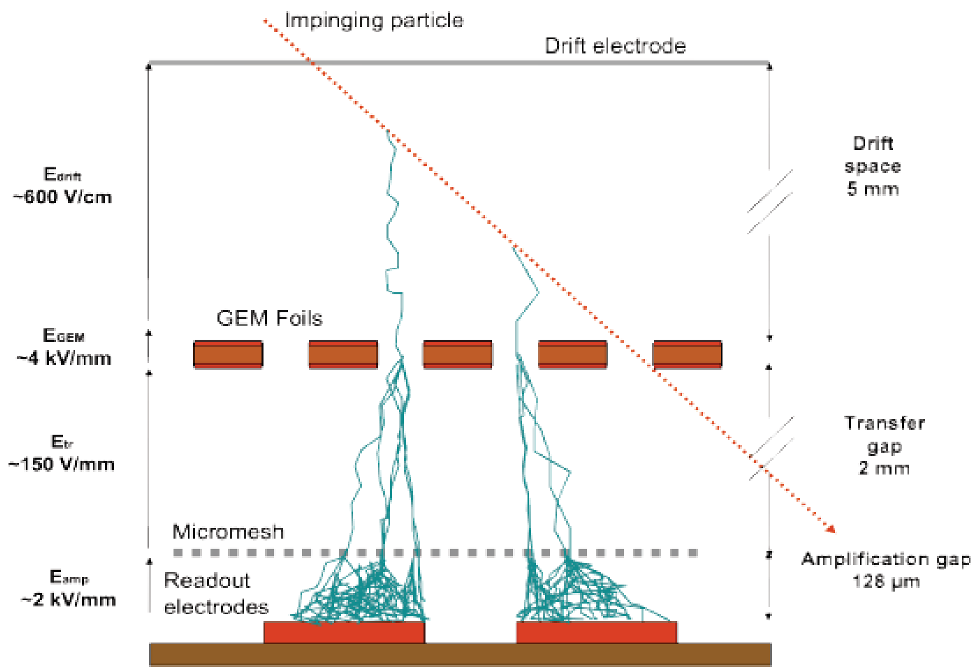
08/29/2011 Rui De Oliveira

GEM x MicroMegas

Discharge rate reduction technologies

Micromegas + 1 GEM foil :

- *1 mm and 2 mm transfer gap*
- *Diffusion of the primary electron cloud*
- *Gain shared between MM and GEM*

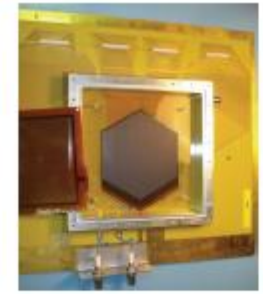


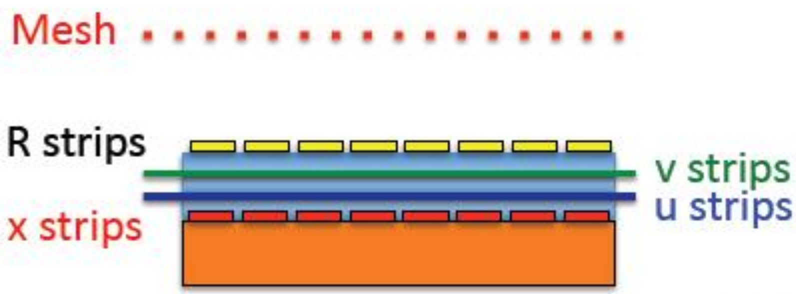
CEA DSM Irfu

M. Vandenbroucke / MPGD2011 / Kobe

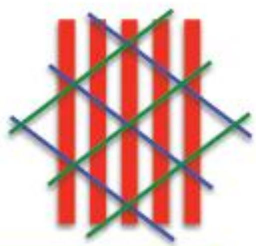
Atlas Development (3D readout)

R19 with xuv readout strips



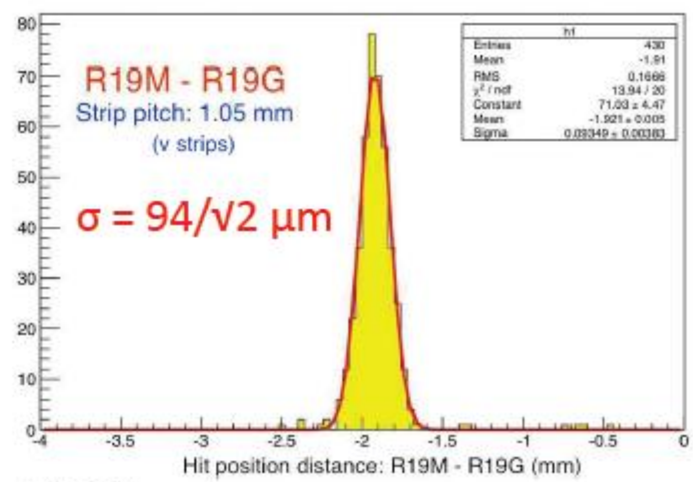


- x strips parallel to R strips
- u,v strips ±60 degree



- Tested two chambers with same readout structure (R19M and R19G) in a pion beam (H6) in July
- Clean signals from all three readout coordinates, no cross-talk
- Strips of v and x layers well matched, u strips low signal, too narrow
- Excellent spatial resolution, even with v and u strips

R19	R	v	u	x
Depth (µm)	0	-50	-100	-150
Strip width (mm)	0.25	0.1	0.1	0.25
Strip pitch (mm)	0.35	0.9	0.9	0.35
Q collected (rel.)		0.84	0.3	1



J. Wotschack / MPGD2011 / Kobe

Conclusions

- GEM Technology suitable for applications with:
  - High rate
  - High spatial resolution
  - Large area
- Micromegas with resistive coating is becoming an attractive option
  - Sparks suppression
  - 2-dimensional readout
  - Relatively simple technology
- Quite a few project working on large area GEM/μM
  - Our activity on the SBS front Tracker@JLab12/Hall A is going to be finalized for production
- Optimal readout chip does not exist; several developments in progress