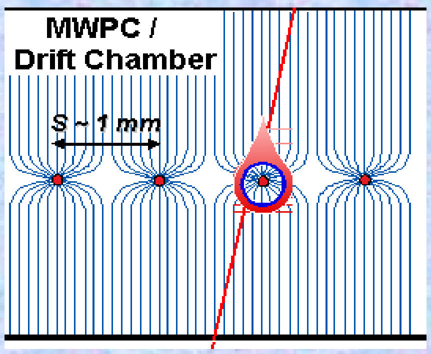
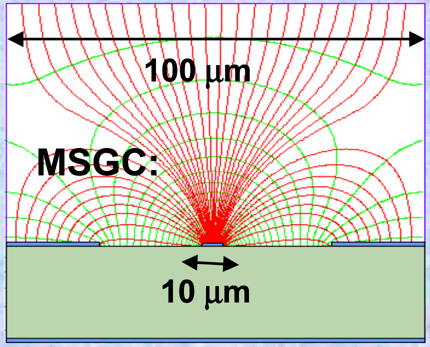
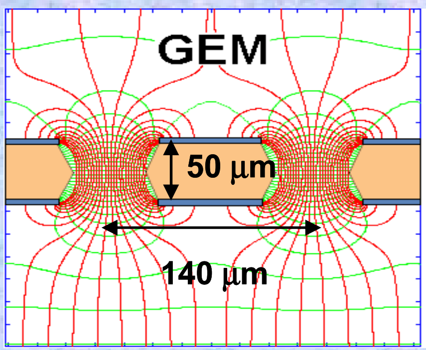
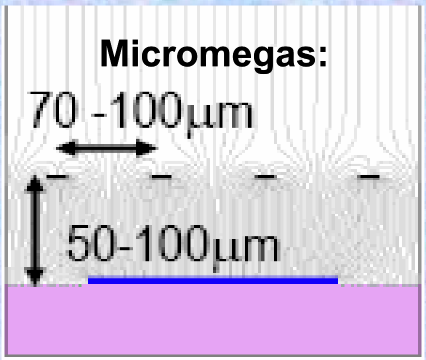








Current Trends in the Micro-Pattern Gas Detectors

Maxim Titov,
CEA SACLAY, DAPNIA, France

OUTLINE / R & D ACTIVITIES:

1. Development of Radiation Hard Technologies
2. State-of-the-art of MPGD (GEM, Micromegas)
3. Technological Aspects of the MPGD Development
4. Detectors and Electronics Integration
5. Software Tools Development for MPGD
6. Advances in Hole-Type Multipliers
7. MPGD Industrial Applications

Micro-Pattern Gas Detectors, Towards R & D Collaboration
CERN, Geneva, September 10-11, 2007

I. Development of Radiation Hard Technologies (Aging, Choice of Contruction Materials, Outgassing, Discharges, Charging-up Effects)

RD10 (1992-1993)

A STUDY TO IMPROVE THE RADIATION HARDNESS OF GASEOUS DETECTORS FOR USE AT VERY HIGH LUMINOSITIES

M. Capeáns, C. Garabatos, R.D. Heuer, R. Mackenzie, T.C. Meyer, and **F. Sauli**
(CERN, Geneva)

T. Mashimo
(ICEPP, Tokyo)

G. Pfister and M. Simona
(Institut Cantonal d'Ecotoxicologie, Geneva)

M. Fraga, M. Salete Leite, E. de Lima, R. Marques, A. Policarpo and K. Silander
(LIP, Coimbra)

RD28 (1993-1996)

DEVELOPMENT OF MICROSTRIP GAS CHAMBERS FOR RADIATION DETECTION AND TRACKING AT HIGH RATES FINAL STATUS REPORT

Presented by F Sauli at the LHCC open meeting, March 13, 1996

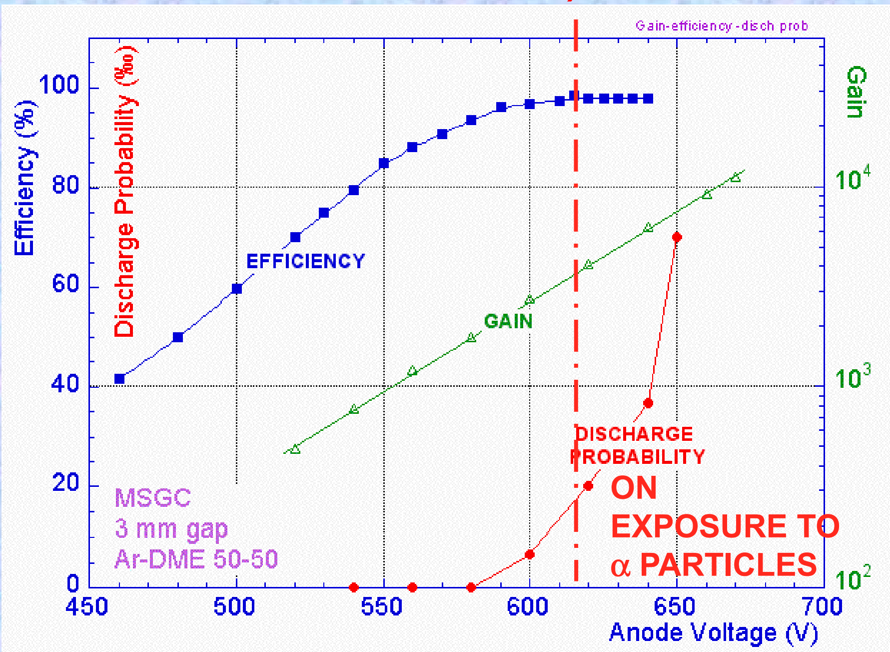
CERN, Geneva, Switzerland
BINP, Budker Institute of Nuclear Physics, Novosibirsk, Russia
CRN-Strasboug, Centre de Recherches Nucléaires, Univ. Luis Pasteur, Strasbourg, France
CRPP-Carleton, Carleton University, Ottawa, Canada
DAPNIA-Saclay, Centre d'Etudes Nucléaires, Saclay, France
DF-INFN-Torino, Dip di Fisica and INFN, Torino, Italy
FERMILAB, Batavia, USA
FPNT-Cracow, Fac. of Phys and Nucl Techn., Univ. of Mining and Metallurgy, Cracow, Poland
HEP-Santiago, Univ of Santiago de Compostela, Spain
IIHE-Bruxelles, Inter-Univ Inst. for High Energy Physics, ULB-VUB, Bruxelles, Belgium
NRCPS-Demokritos, Inst. of Nucl Phys. and Inst. of Micro Electronics, Attiki, Greece
IP-Prague, Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
IP-Comenius, Institute of Physics, Comenius University, Bratislava, Slovakia
IP-Kosice, Inst. of Physics of the Slovak Academy of Sciences, Kosice, Slovakia
IPN-Lyon, Institut de Physique Nucléaire, Lyon, France
ISA-Aarhus, Institute for Synchrotron Radiation, Aarhus, Danemark
ITEP-Moscow, Institute for Theoretical and Experimental Physics, Moscow, Russia
JINR, Dubna, Russia
LIP-Coimbra, Lab. de Instrumentação e Fisica Experim de Particulas, Univ. Coimbra, Portugal
LN-INFN-Frascati, Laboratori Nazionali INFN, Frascati, Italy
LN-INFN-Legnaro, Laboratori Nazionali INFN, Legnaro, Italy
LN-INFN-Gran Sasso, Laboratori Nazionali, Gran Sasso, Italy
LPI-Moscow, Lebedev Physical Institute, Moscow, Russia
LPPE-Mons, Laboratoire de Physique des Particules Elementaires, Mons, Belgique
MPI-Heidelberg, Max-Planck Inst. für Kernphysik, Heidelberg, Germany
NIKHEF, Amsterdam, The Netherlands
NPI-Moscow, Nucl. Physics Institute, Moscow State University, Moscow, Russia
PD-Carleton, Physics Dept., Carleton University, Ottawa, Canada
PD-Michigan, Physics Dept., University of Michigan, Ann Arbor, USA
PD-Northwestern, Physics Dept. Northwestern University, Evanston, USA
PD-Birmingham, Physics Dept., Birmingham University, Birmingham, UK
PD-Liverpool, Physics Dept., Liverpool University, Liverpool, UK
PD-Manchester, Physics Dept., Manchester University, Manchester, UK
PHASE, CRN, Univ Luis Pasteur, Strasbourg, France
RAL, Rutherford Appleton Laboratory, Chilton, Didcot, UK
SUNY, Stony Brook, USA
TA&M-PD, Physics Dept, Texas A&M University, College Station, USA
TRIUMF, Vancouver, Canada
UC-London, University College, London, UK
WIS, Weizmann Institute of Sciences, Rehovot, Israel

(RD10 & RD28 & new LHC developments has a greatest impact on our understanding of radiation hardness in all types of gas detectors)

Aging and radiation hardness of gas detectors → See M. Capeans talk

Micro-Strip Gas Chamber (MSGC)

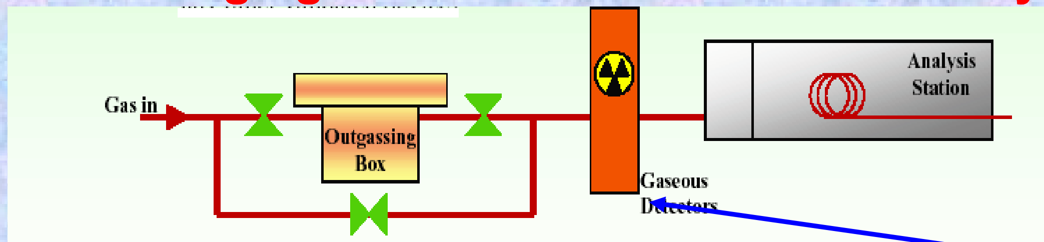
RATE CAPABILITY > 10^6/mm^{2}s;SPACE ACCURACY ~ 40 µm;2-TRACK RESOLUTION ~ 400 µm



Major processes leading at high rates to MSGC operating instabilities:

- **Substrate charging up**
- **Micro-discharges**
- **Deposition of polymers (aging)**

RD28: aging results from MSGC community

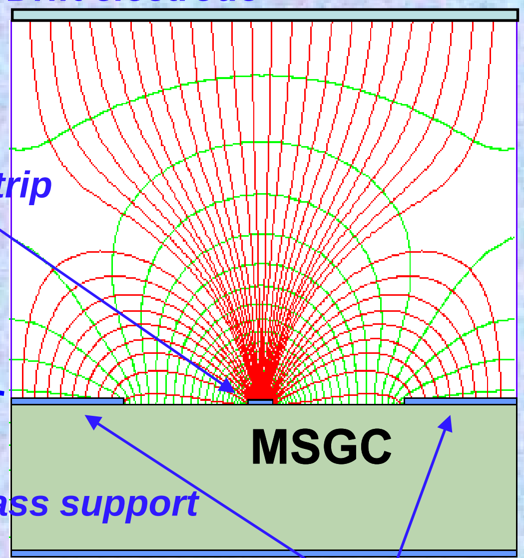


**(R. Bouclier et al., NIMA381(1996) 289,
M. Capeans, ICFA Instrum. Bull.24(2002)85-109)**

**(NASA DATABASE - Outgassing Data for selecting Spacecraft materials
http://epims.gsfc.nasa.gov/og/index.cgi)**

Drift electrode

Anode strip

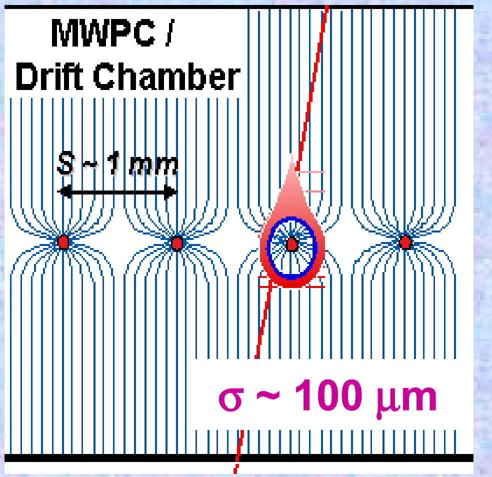


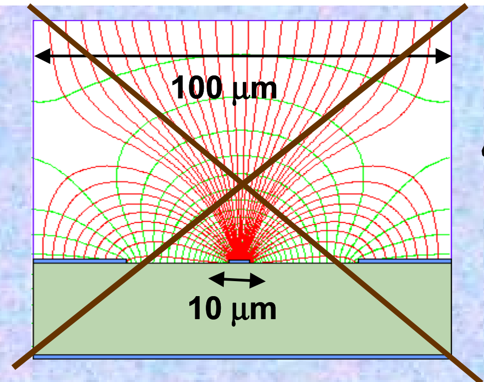
Glass support

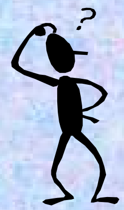
Back plane

Cathode strips

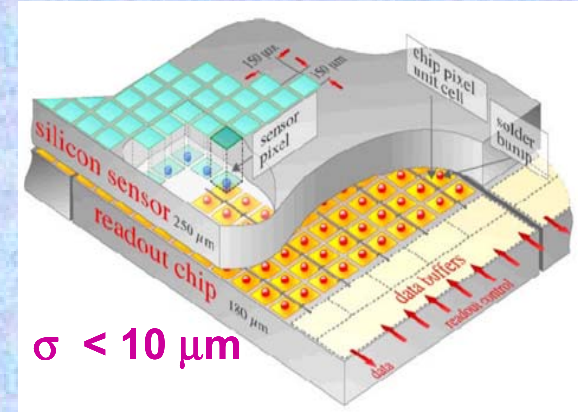
II. State-of-the-art of MPGD detectors
(stability studies, intrinsic detector performance optimization)

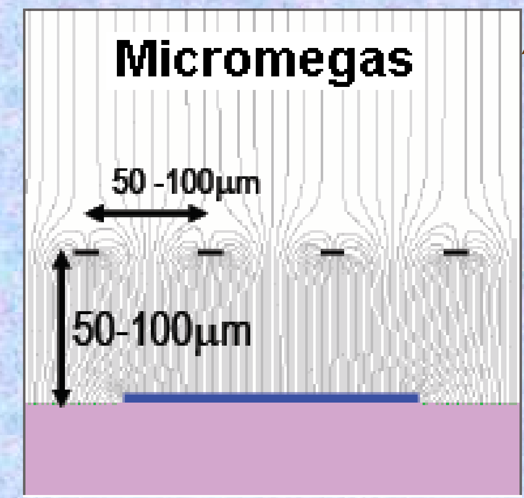






Novel Pixel System:



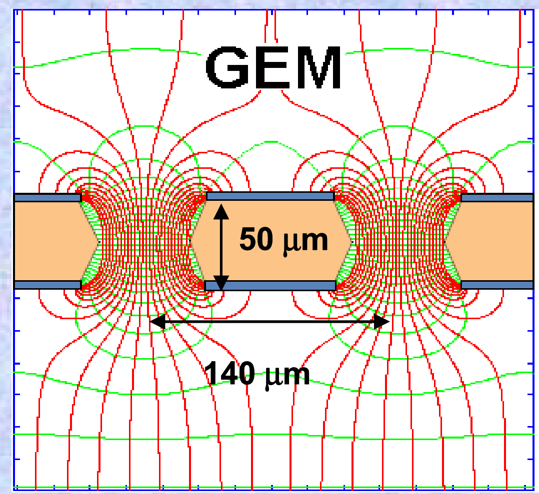


LHC (SLHC):

- Radiation hard concepts
- High granularity

ILC:

- Ultra-high precision
- Minimal material budget



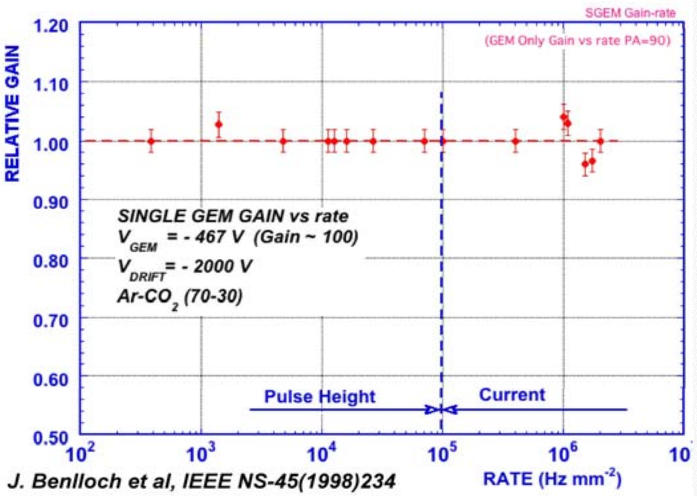
Many detector issues to be addressed for the SLHC and ILC
→ Need for a common R & D efforts

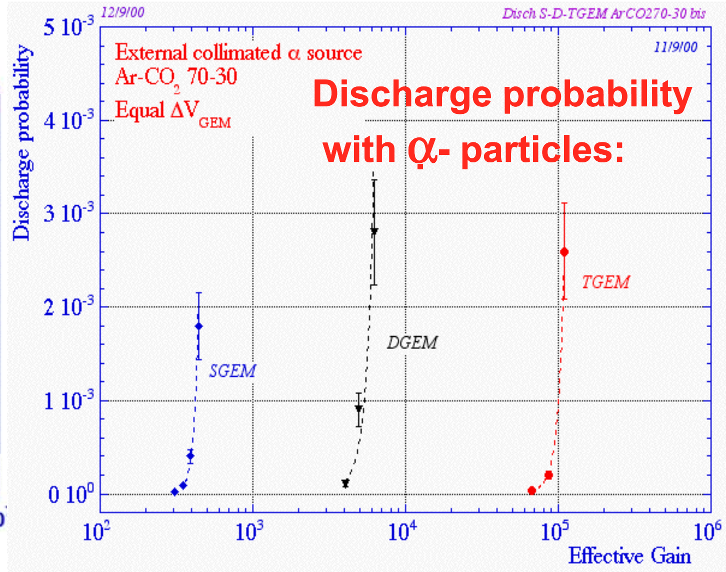
Gas Electron Multiplier (GEM)

F. Sauli, NIM A386(1997) 531;
F. Sauli, http://www.cern.ch/GDD

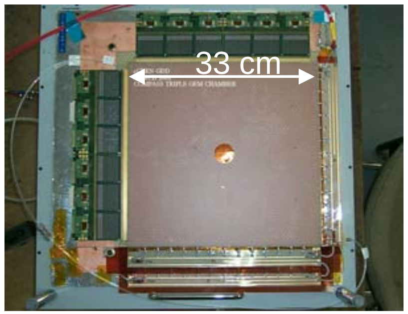
Full decoupling of amplification stage (GEM) and readout stage (PCB, anode)

High-rate capability > 10^5 Hz/mm^2



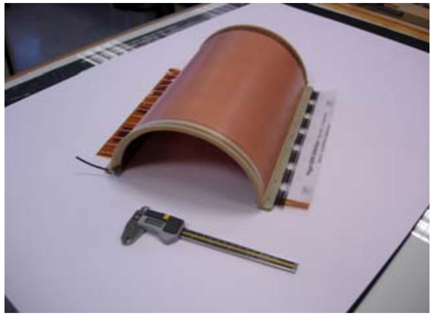


Amplification and readout structures can be optimized independently !

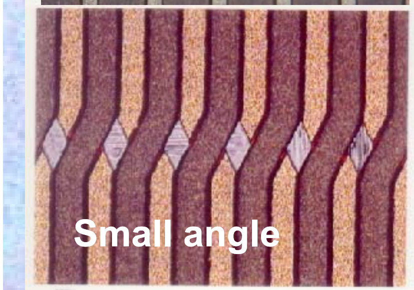


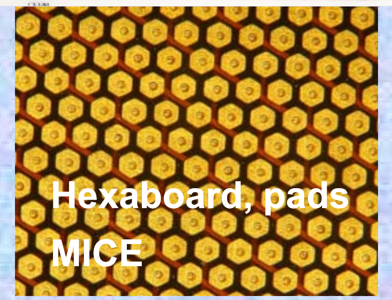
Compass

Totem



NA49-future





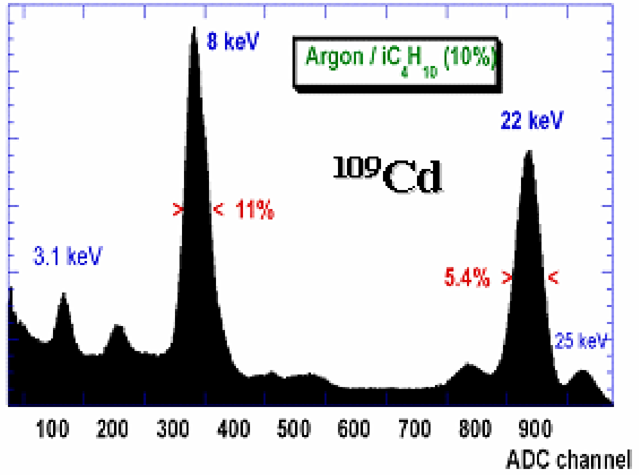
Novel GEM Developments at CERN → see L. Ropelewski talk

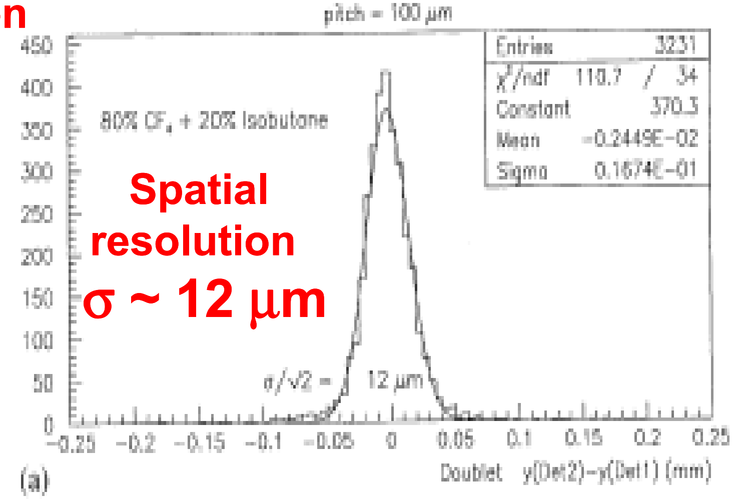
MICROMEsh GAseous Structure (Micromegas)

Y. Giomataris, NIM A376(1996) 29

Parallel plate multiplication in thin gaps between a fine mesh and anode plate

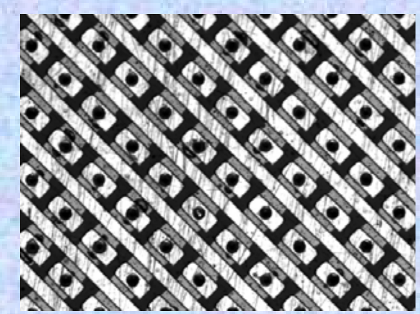
Small gap→ good energy resolution



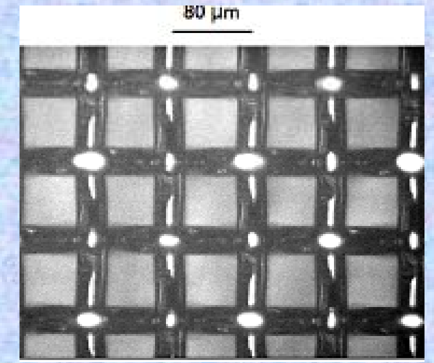


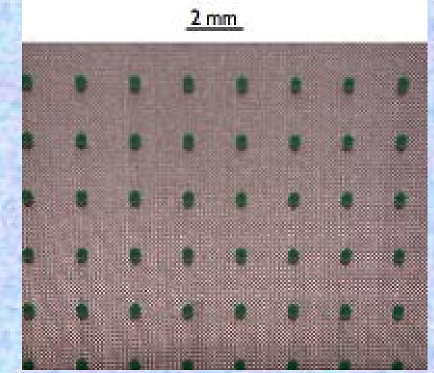
J. Derre et al, NIM A459 (2001) 523

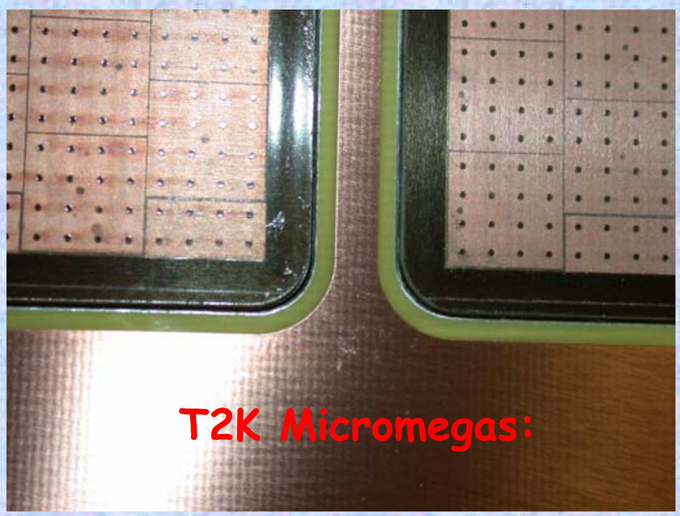
CAST readout:

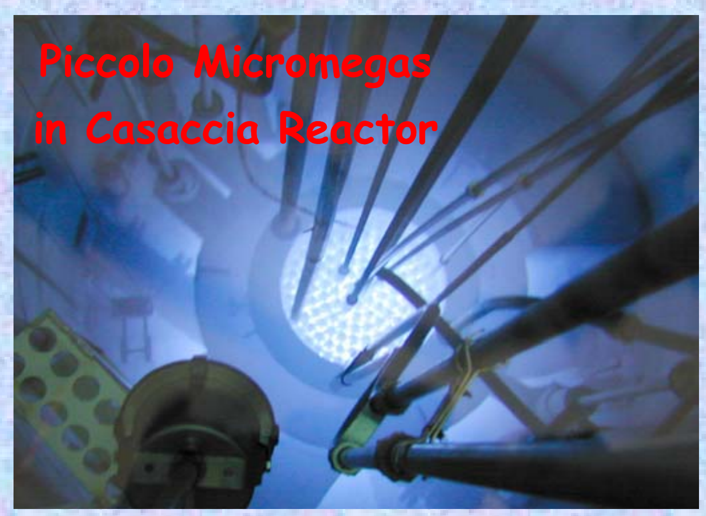


"Bulk" Micromegas:



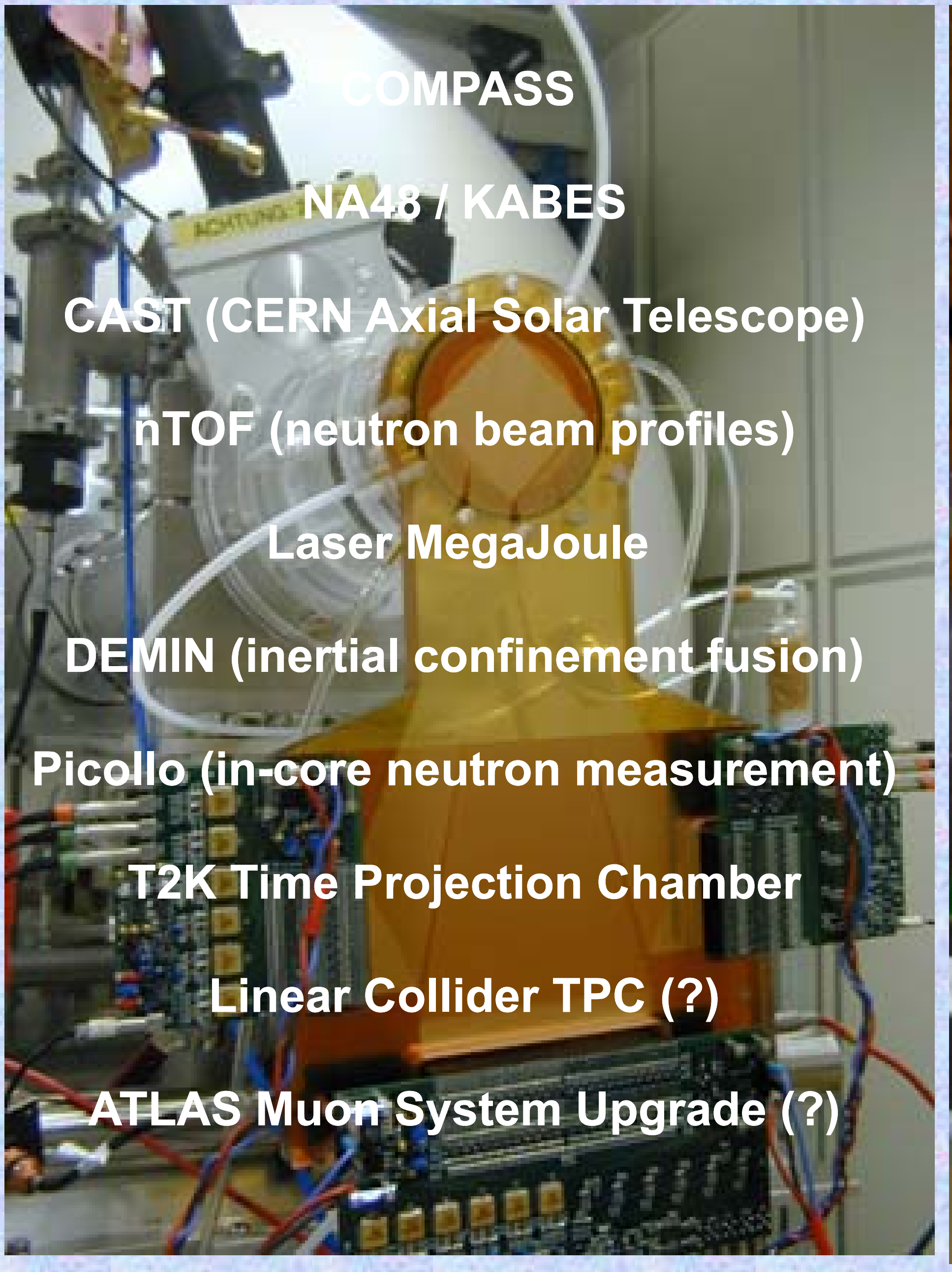




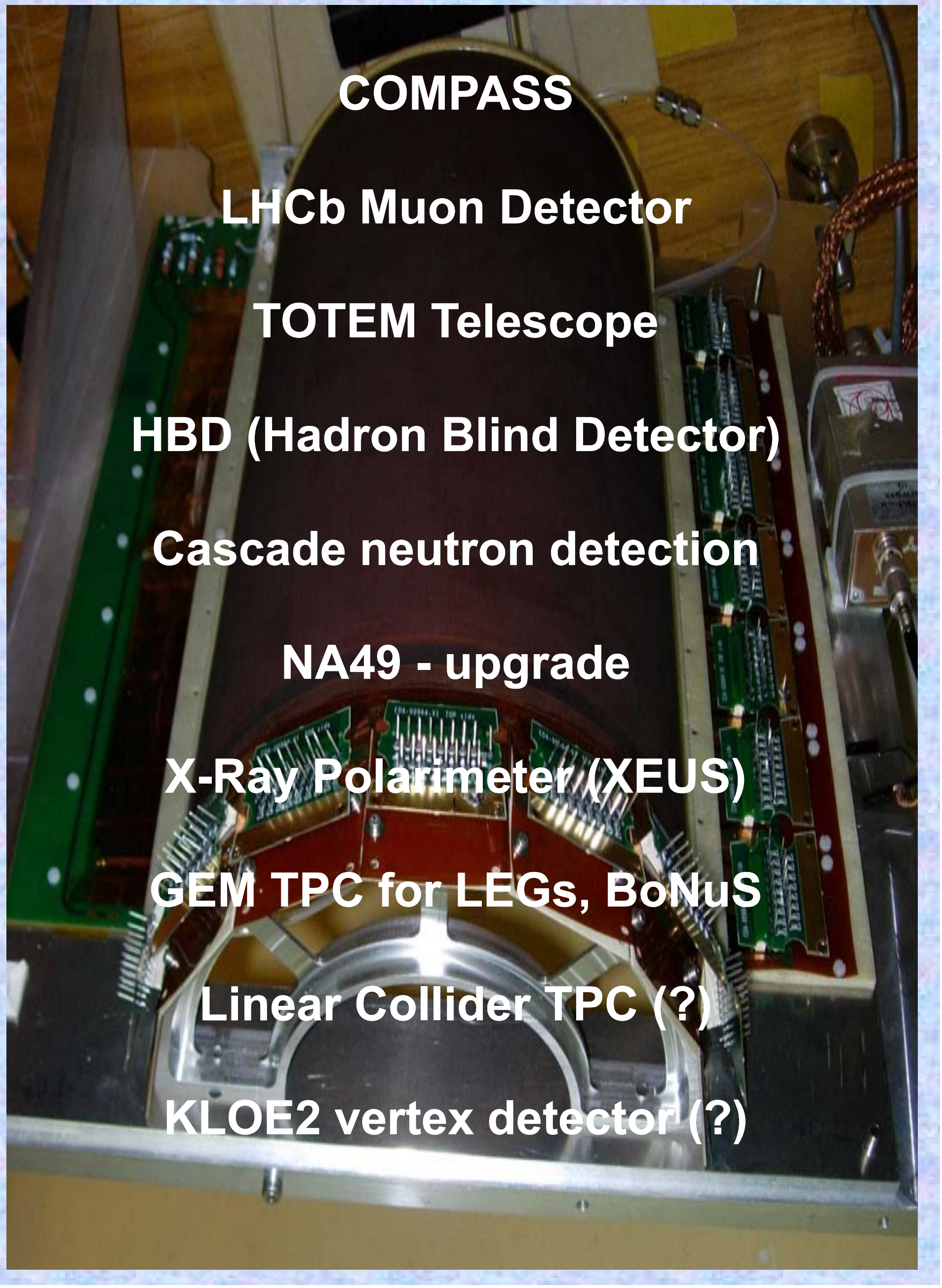


Latest Developments with Micromegas and R&D → see I. Giomataris, D. Attie talks

Micromegas and GEM in Current/Future HEP Experiments



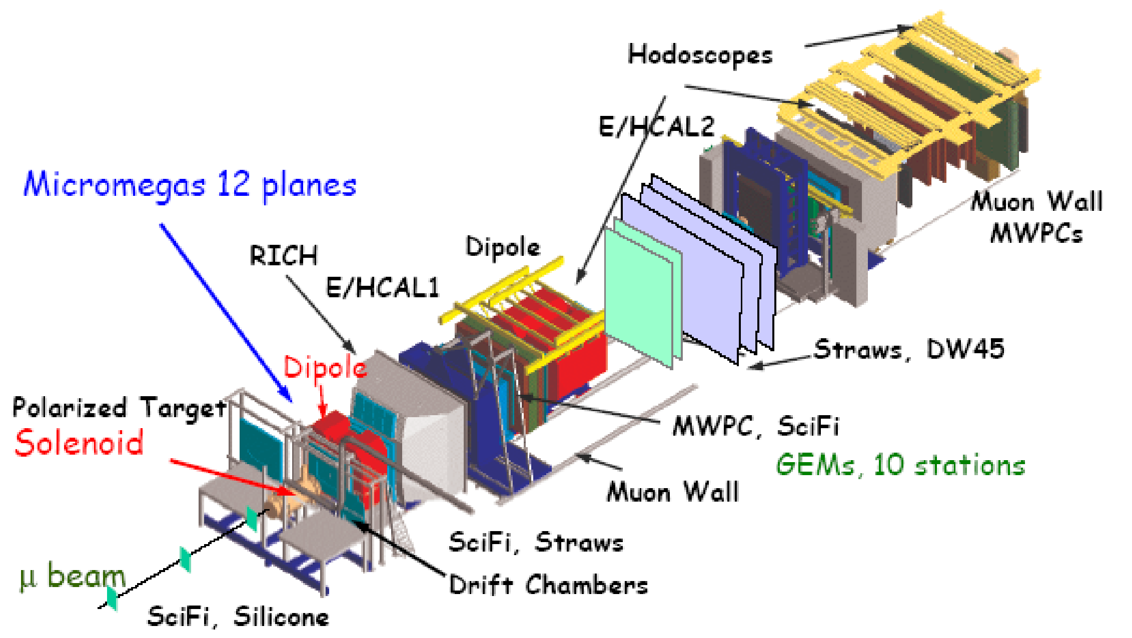
- COMPASS
- NA48 / KABES
- CAST (CERN Axial Solar Telescope)
- nTOF (neutron beam profiles)
- Laser MegaJoule
- DEMIN (inertial confinement fusion)
- Picollo (in-core neutron measurement)
- T2K Time Projection Chamber
- Linear Collider TPC (?)
- ATLAS Muon System Upgrade (?)



- COMPASS
- LHCb Muon Detector
- TOTEM Telescope
- HBD (Hadron Blind Detector)
- Cascade neutron detection
- NA49 - upgrade
- X-Ray Polarimeter (XEUS)
- GEM TPC for LEGs, BoNuS
- Linear Collider TPC (?)
- KLOE2 vertex detector (?)

GEM / Micromegas in COMPASS - Textbook of Modern Physics

High Rate Forward spectrometer: COMPASS beam ~ 5* 10^7 muons/s on ^{6}LiD target

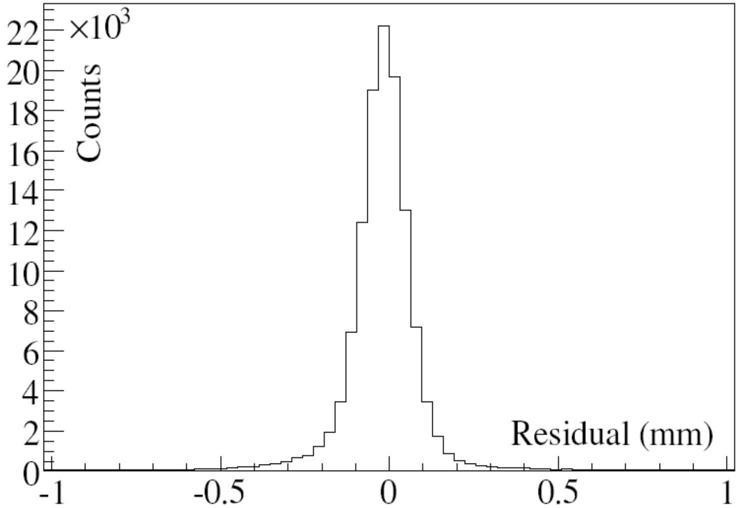


22 TRIPLE GEM DETECTORS
(31*31 cm^2)
& 12 MICROMEGAS PLANES
(40*40 cm^2)

High Rate /
High Precision /
Low Mass Detectors:

25 kHz/mm^2

GEM resolution σ ~ 70 μm

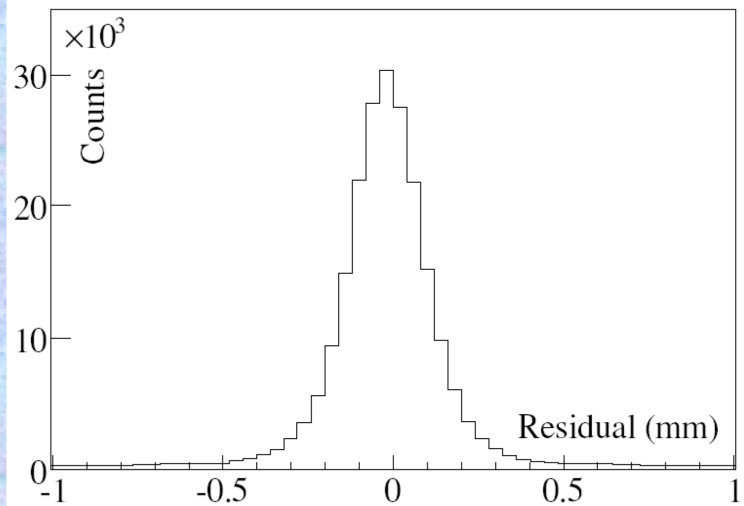


AVERAGED OVER (ALL PLANES):

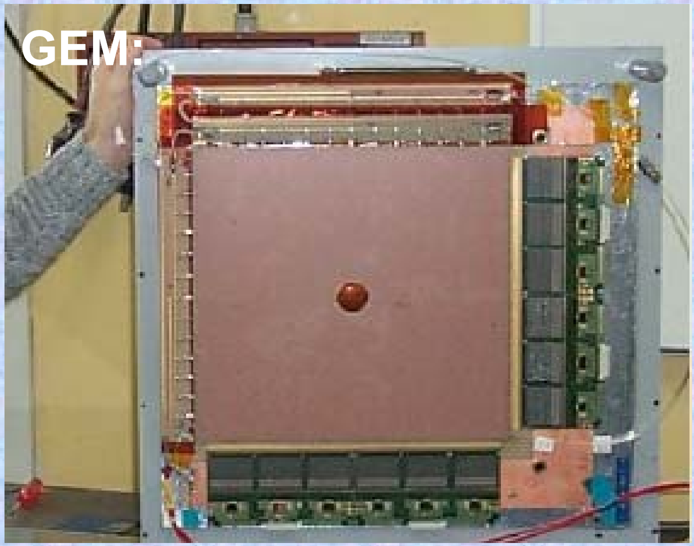
Readout pitch ~ 400 μm

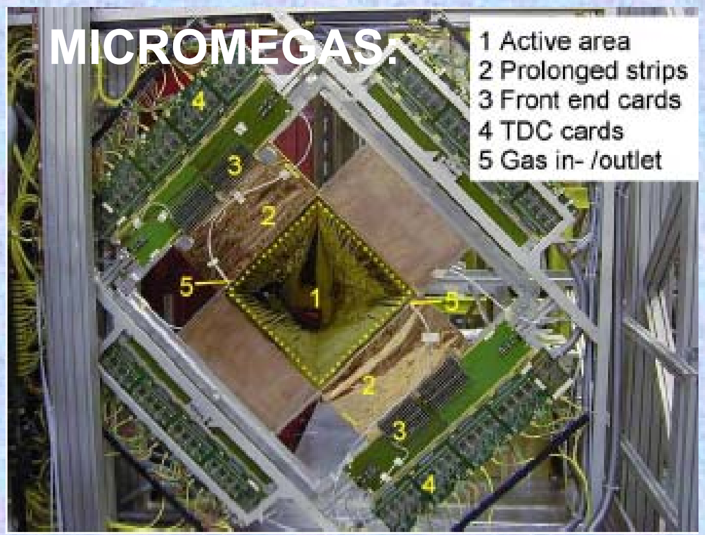
AFTER DECONVOLUTION OF TRACK ERROR

Micromegas resolution σ ~ 90 μm



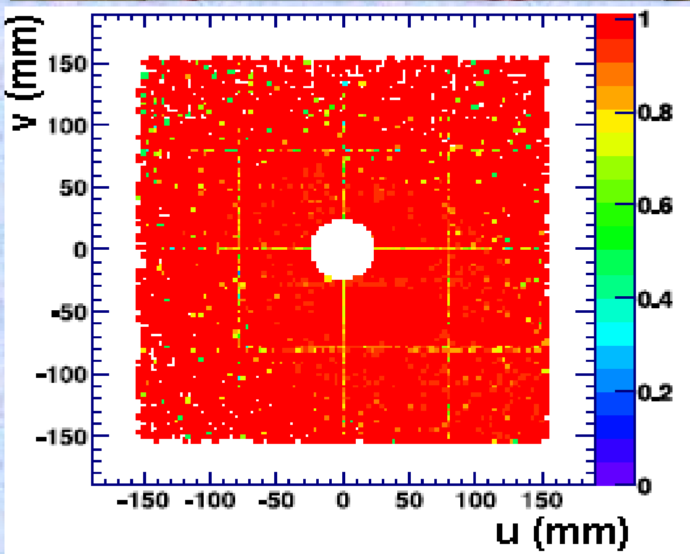
GEM / Micromegas in COMPASS - 4 Years of Experience





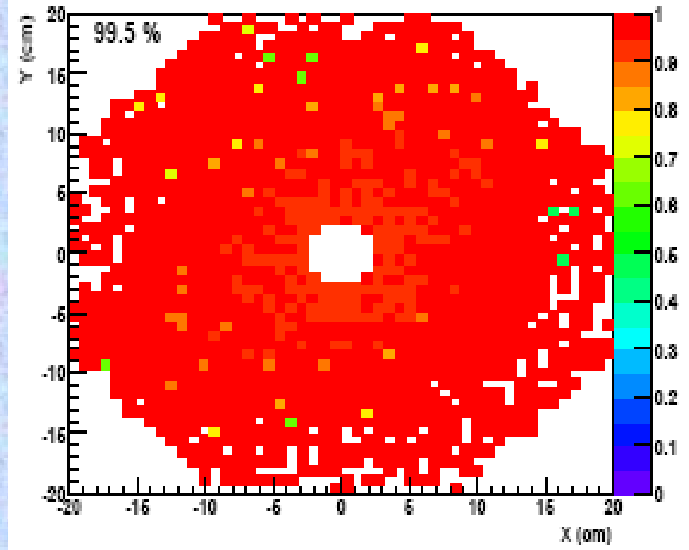
RELIABLE OPERATION in 2002 – 2006

NO SIGN OF AGING



UNIFORMITY OF TRACKING EFFICIENCY:

(ε > 95 %)



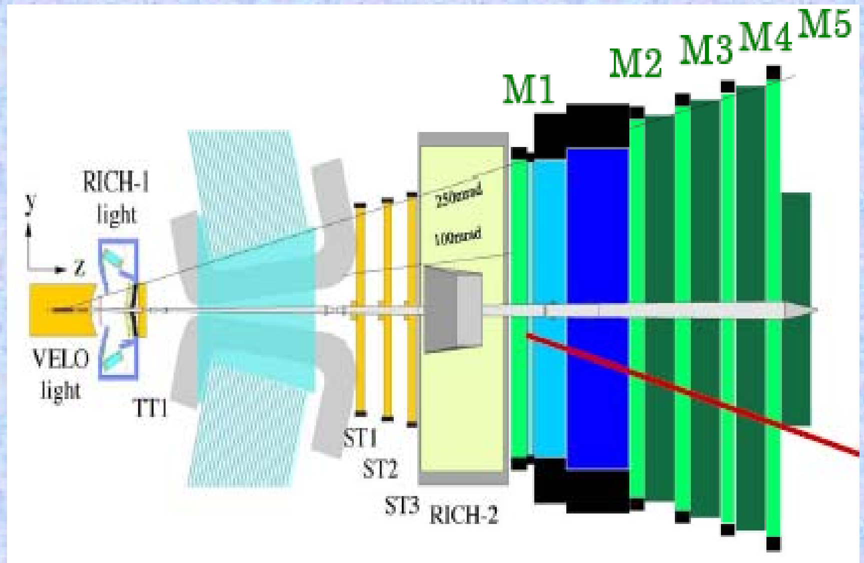
B. Ketzer et al, NIM A535 (2004) 314

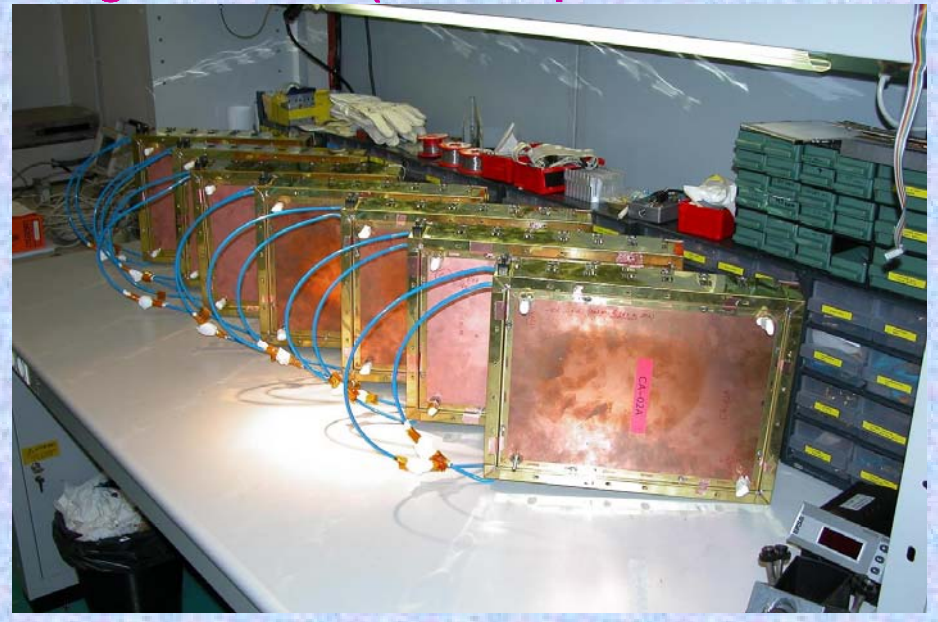
F. Kunne, 2006 IEEE NSS/MIC Conference Record

Future GEM developments for COMPASS and PANDA experiments→ see B. Ketzer talk

Triple-GEM for Triggering in the LHCb Muon System

12 Triple GEM Detectors in the innermost region of M1: (rates up to 0.5 MHz/cm^2)

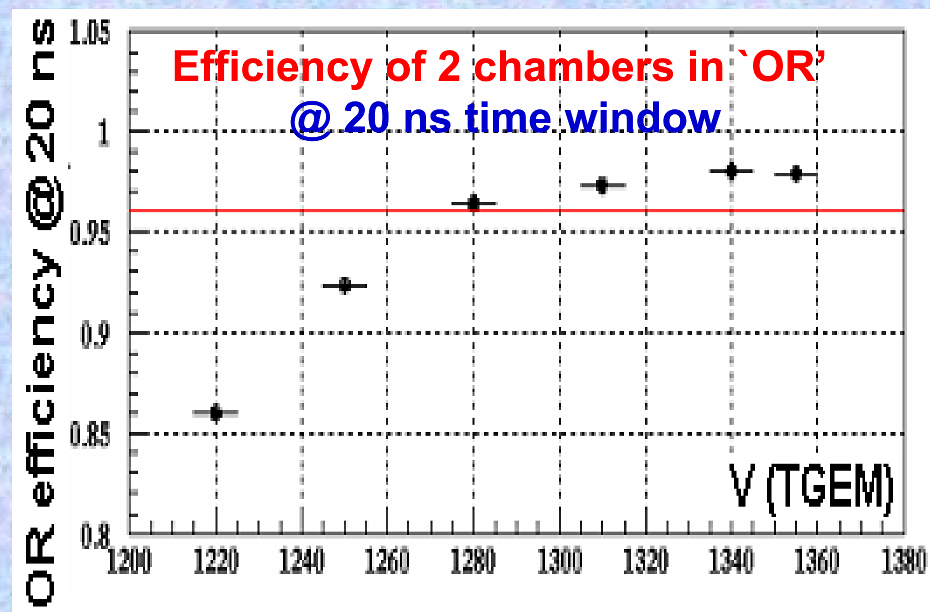




Triple GEM (~ 20 * 25 cm^2)
with Ar/CF_4/CO_2 (45:40:15):

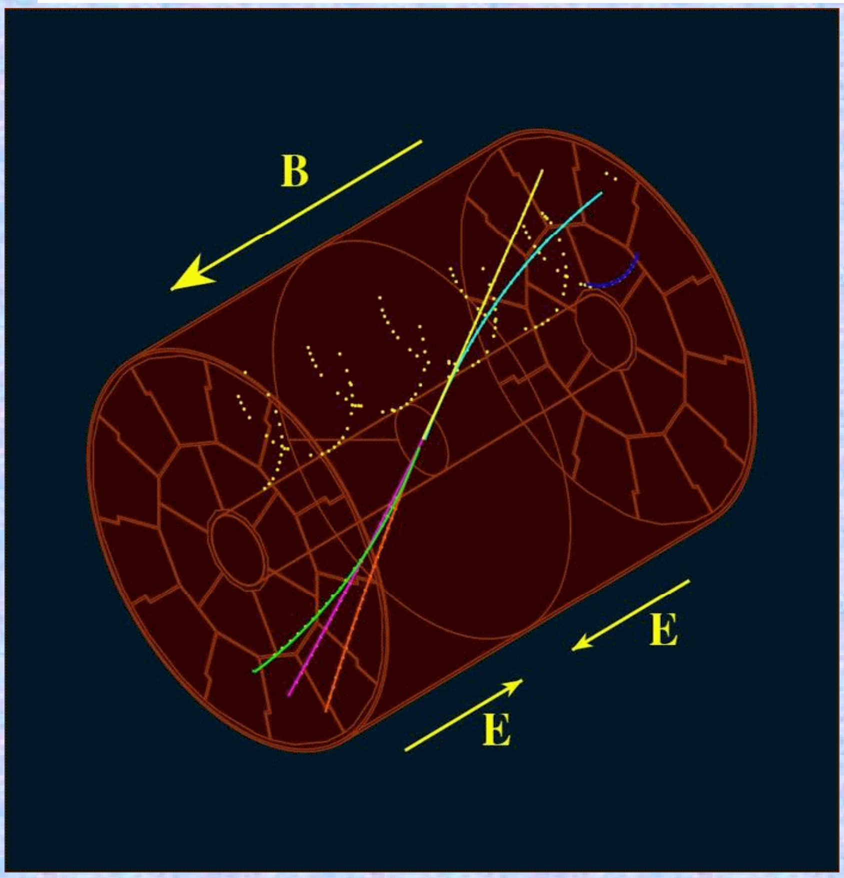
Time resolution: RMS ~ 4.5 ns

M. Alfonsi. IEEE TNS-51(5) (2004) 2135



GEM Activities at INFN
(GEM @ LHCb, Cylindrical GEM @ KLOE
→ see M. Alfonsi talk

Time Projection Chamber for International Linear Collider



☺ Future readout concepts for TPC : GEM, Micromegas

GEM: ☺ Tiny E x B effect,
• Only fast electron signal (no ion tail)
• Narrow pad res. function → lower gain
• Freedom in readout structures

Idea (1976): proposal for PEP4 at LBL
Proven technology: DELPHI, ALEPH (LEP), Ceres, NA49, STAR (heavy-ion experiments)
Future experiments: ALICE (LHC), T2K, ILC

	STAR	ALICE	ILC
Inner radius (cm)	50	85	32
Outer radius (cm)	200	250	170
Length (cm)	2 * 210	2 * 250	2 * 250
Charge collection	wire	wire	MPGD
Pad size (mm)	2.8 * 11.5 6.2 * 19.5	4 * 7.5 6*10(15)	2 * 6
Total # pads	140000	560000	1200000
Magnetic field [T]	0.5	0.5	4
Gas Mixture	Ar/CH4 (90:10)	Ne/CO2 (90:10)	Ar/CH4/CO2 (93:5:2)
Drift Field [V/cm]	135	400	230
Total drift time (μs)	38	88	50
Diffusion $\sigma_T (\mu m/\sqrt{cm})$	230	220	70
Diffusion $\sigma_L (\mu m/\sqrt{cm})$	360	220	300
Resolution in rφ (μm)	500-2000	300-2000	70-150
Resolution in rz (μm)	1000-3000	600-2000	500-800
dE/dx resolution [%]	7	7	< 5
Tracking efficiency[%]	80	95	98

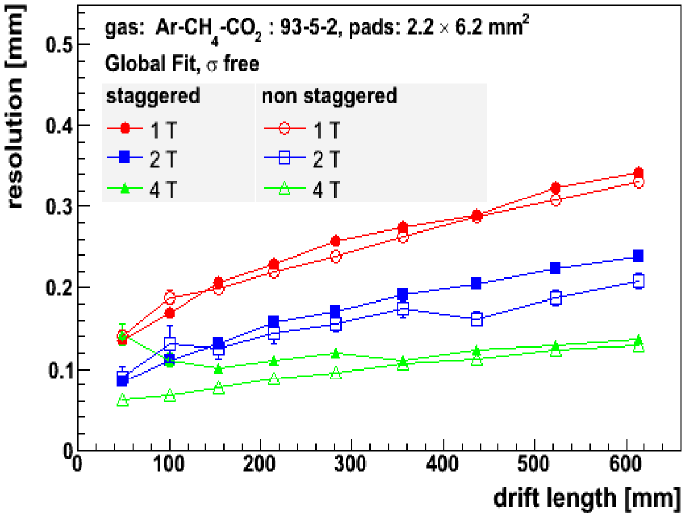
The LCTPC collaboration: key aspects of activity → see K. Dehmelt talk

Ongoing R&D for the MPGD ILC-TPC

MPDG TPC HAS DEMONSTRATED ITS POTENTIAL TO ACHIEVE $\sigma \sim 100\ \mu m$

Triple GEM: ← **Single Point Resolution** → **Micromegas:**

(with resistive anode readout)

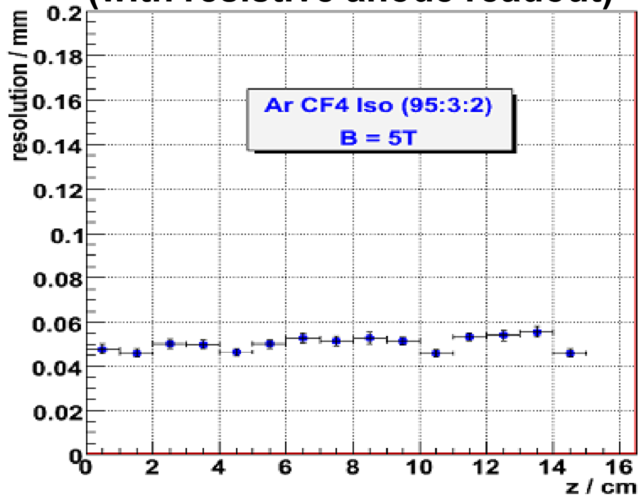


AT B=4 T SPATIAL RESOLUTION IS DOMINATED BY READOUT STRUCTURE (2 * 6 mm² PADS)

M. Janssen, 2006 IEEE NSS/MIC Conference Record

determined by

- Transverse diffusion
- Readout geometry
- Defocussing (3-GEM)



THE NARROW SIGNAL SPREAD (PRF ~ 10 μm) REQUIRES SIGNAL BROADENING FOR O(1 mm) PADS

(P. Colas et al, arXiv: physics/0703243)

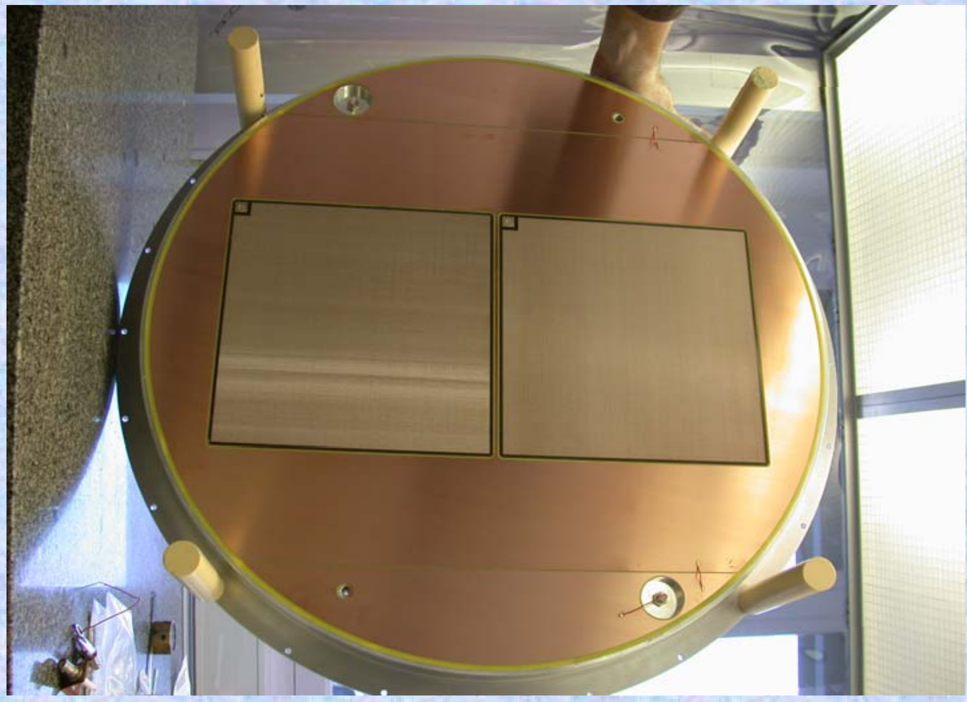
R & D Activities:

- Single and two-track resolution (in presence of beam bkg)
  → gas mixture & ion feedback optimization
- Endplate design for minimal material
  → detector & electronics integration

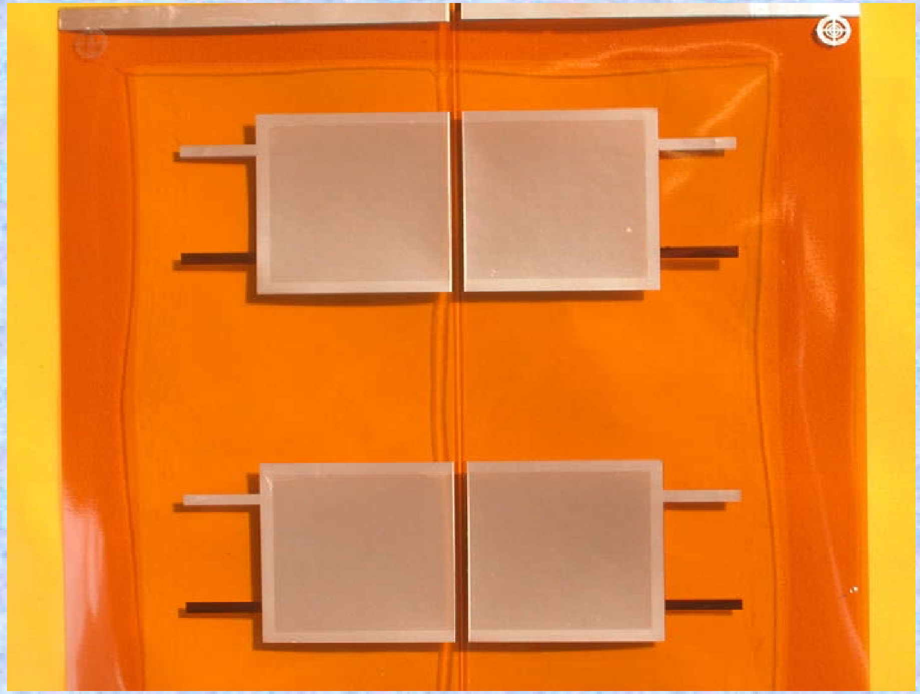
MPDG-TPC Performance & Charge dispersive readout → see P. Colas, A. Bellerive talks

III. Technological Aspects of the MPGD Development (industrialization and manufacture of large size detectors, quality control, assembly and system aspects)

“BULK” MICROMEGAS @HARP ENDPLATE:



2 GEM GLUED TOGETHER @ CERN:

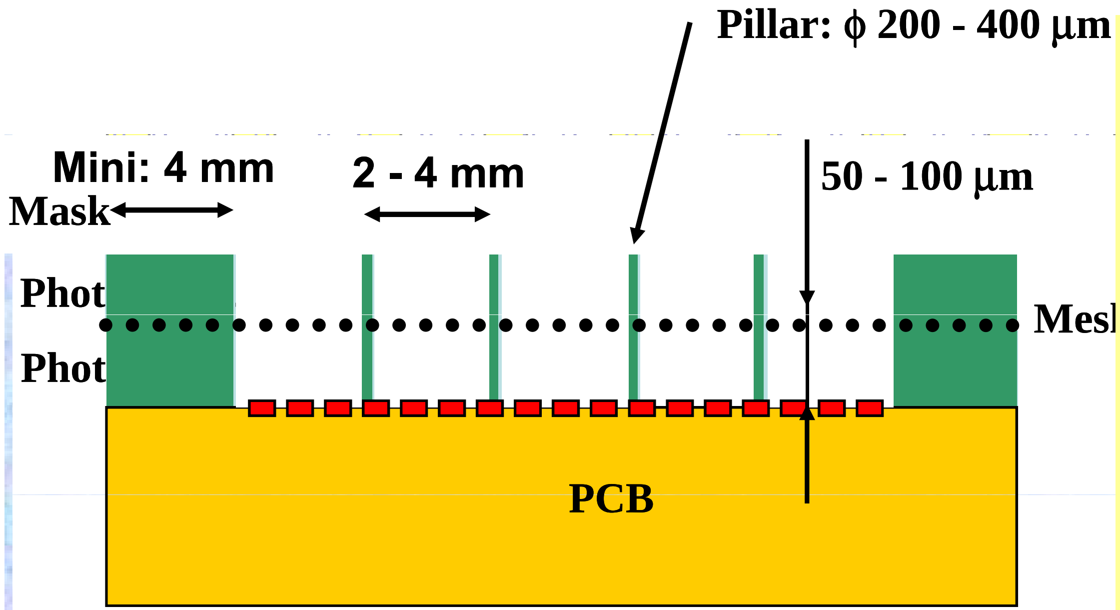


Talks at workshop → R. de Oliveira, A. Delbart, S. Pinto, K. Kurvinen, N. Smirnov

New Fabrication Technology "Bulk" Micromegas

Large area/robustness, industrial process
Low material detectors
no separate assembly of PCB & Micromesh grid

1) PCB
2) Photoresistive film lamination (50 - 150 μm)
3) Mesh lamination (ϕ 19 μm 500 LPI)
4) Photoresistive film lamination (50 - 150 μm)
5) UV exposure through mask
6) Development (chemical solution)



I. Giomataris et al, NIM A560 (2006) 405

T2K Micromegas / TPC:

~ 10 m^2 TPC endplate
will be equipped in 2009 with
72 Bulk Micromegas (34 * 36 cm^2)

J. Bouchez, NIMA574(2007) 425

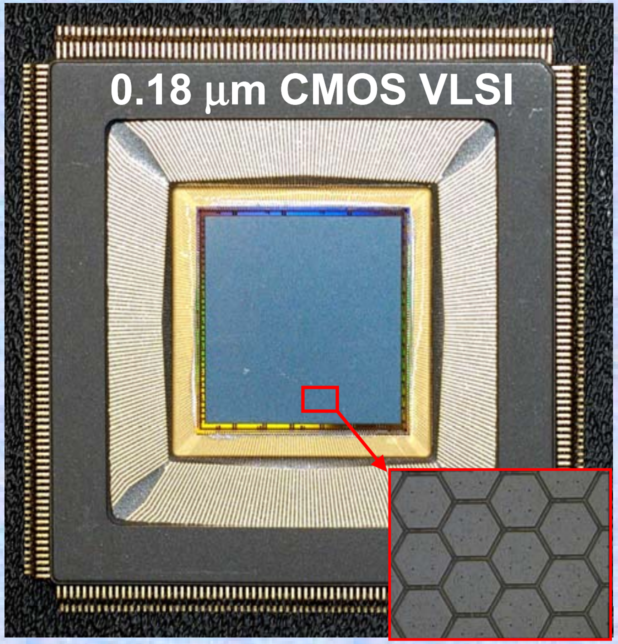
BULK MICROMEGAS →
see A. Delbart talk

R&D for ATLAS Muon Upgrade:
(trigger & tracking in single chamber)

Replace muon chambers in regions
with highest counting rates
(few kHz/cm^2 @ L=$10^{35}cm^{-2}$ s^{-1},
mostly from neutrons and γ's)

Need large-size detectors (1 * 2 m)
→ See J. Wotschak talk

IV. Detector and Electronics Integration (CMOS readout concept, Ingrid Technology, MPGD ASICs)

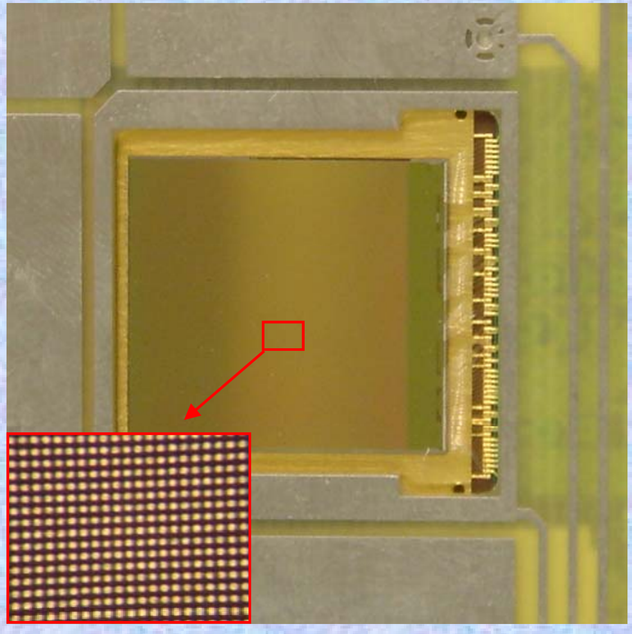


ANALOG VLSI ASIC@ PISA
→ See R. Bellazzini talk

E .Costa, Nature 411 (2001) 662
R. Bellazzini, NIMA535 (2004) 477

MEDIPIX2 / TIMEPIX CHIP
→ See M. Campbell talk

P. Colas, NIMA535 (2004) 506
A. Bamberger, NIMA573(2007) 361



Novel ASIC R&D Developments for the MPGD
(… not limited to CMOS readout …)

→ see W. Riegler, L. Musa, P. Baron, W. Snoyes, N. Malakhov, G. Felici, J. Pouthas, T. Tanimori talks

Pixel Readout for Gaseous Detectors

Gas Detector Readout by multi-pixel CMOS array (used as charge collecting anode)

EXPERIMENTAL OPPORTUNITIES:`

1) Reconstruction of photoelectrons from X-Ray (2-10 keV) conversions

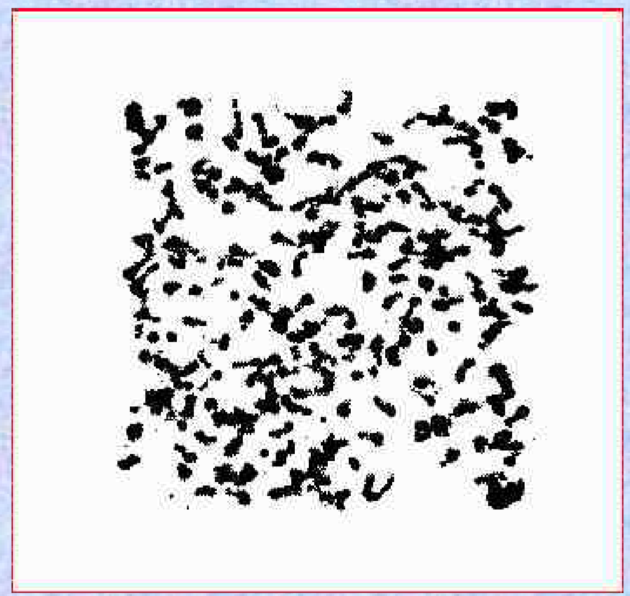
2) High-Rate Particle Tracking →
no ambiguity with multi-track & multi-hit events

Time Projection Chamber (TPC, μTPC)
→ precision 3-D track reconstruction

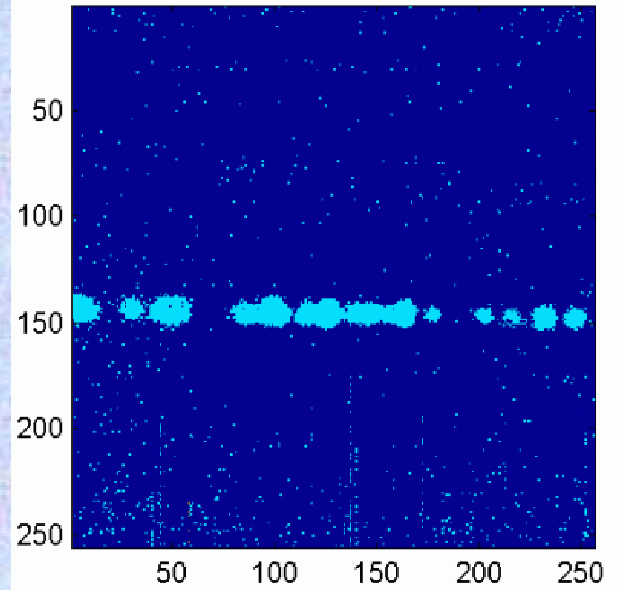
3) Single Photon Detection

4) Advanced Compton Telescope & Low energy nuclear recoil reconstruction in WIMP or neutrino interactions
→ both direction and dynamics of photoelectron or nuclear recoil can be accurately tracked

GEM + VLSI ASIC



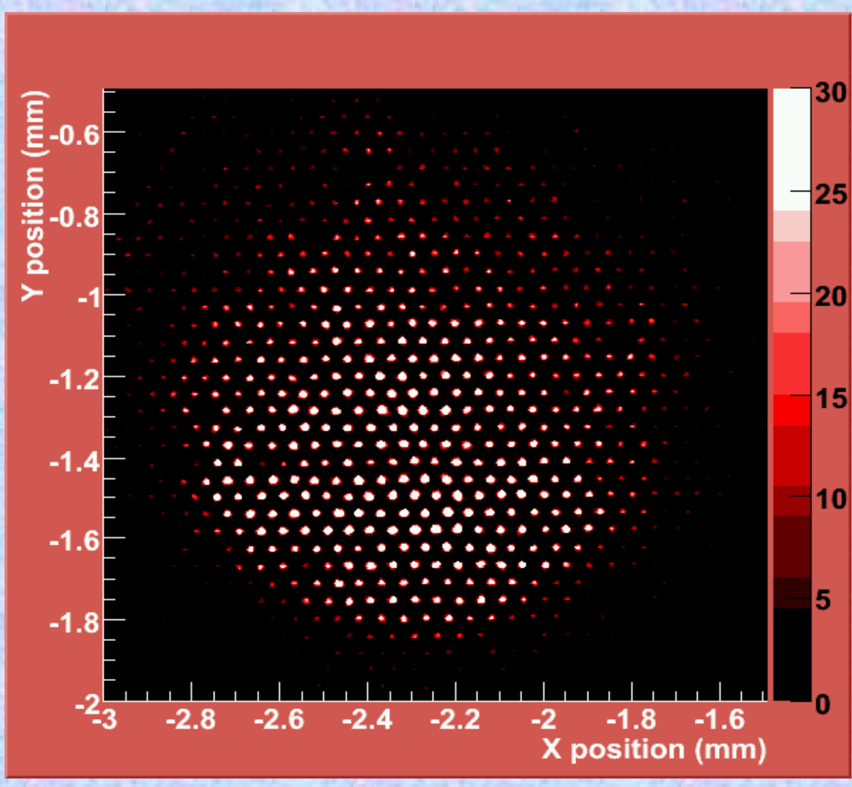
GEM + Medipix2 (5 GeV e-)



Single Photon Detection @ GEM + VLSI pixel ASIC

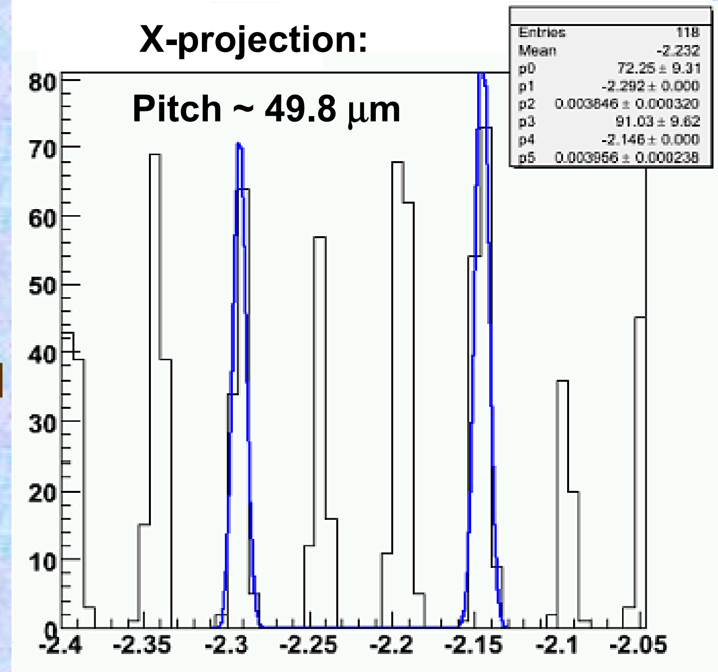
"SELF- PORTRAIT" OF GEM AMPLIFICATION STRUCTURE

- UV photo-detector (semi-transparatent CsI + GEM)
  - Single photoelectrons entering GEM hole
    - GEM foil & CMOS chip pitch (50 µm)



X – PROJECTION

Intrinsic resolution of the read-out system (S/N and systematics):



Center of "gravity" of single electron avalanche $\sigma \sim 4\ \mu m$

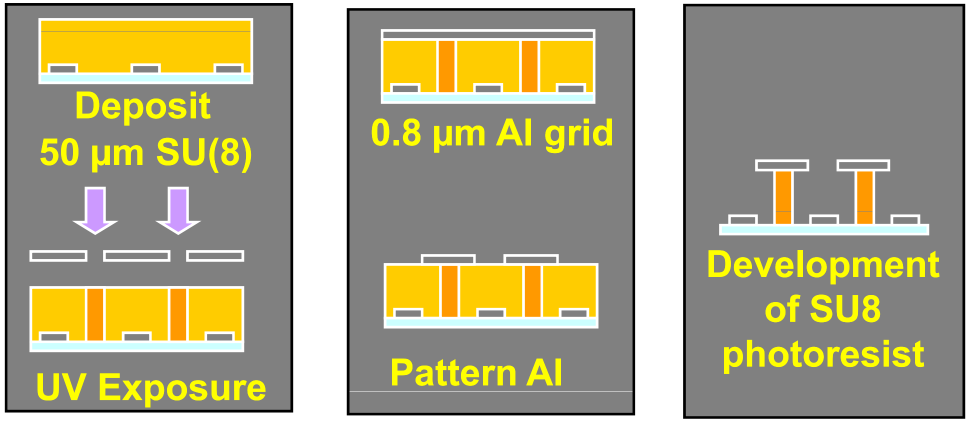
Resolution is not degraded by avalanche spread in the GEM amplification system

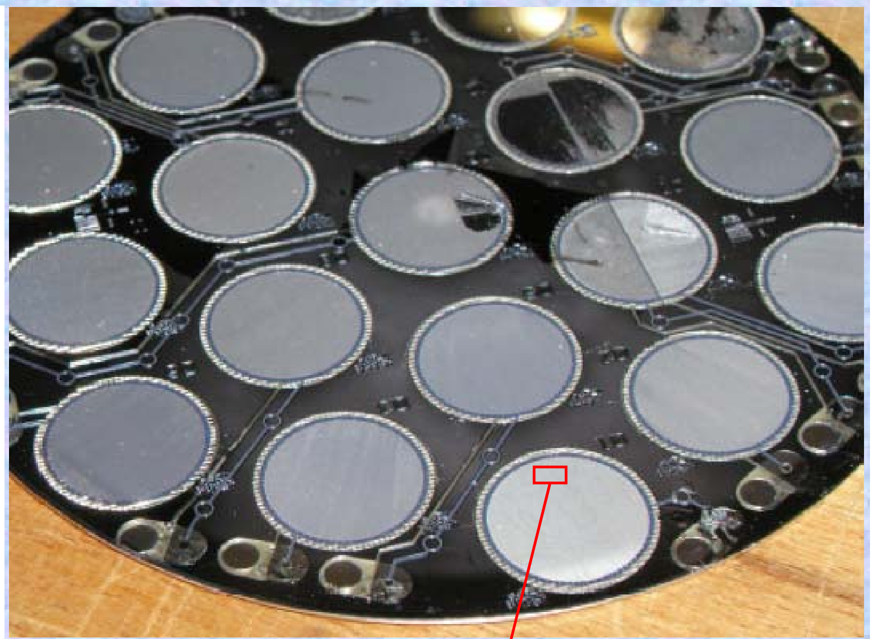
R. Bellazzini et al, arXiv: physics/0703176

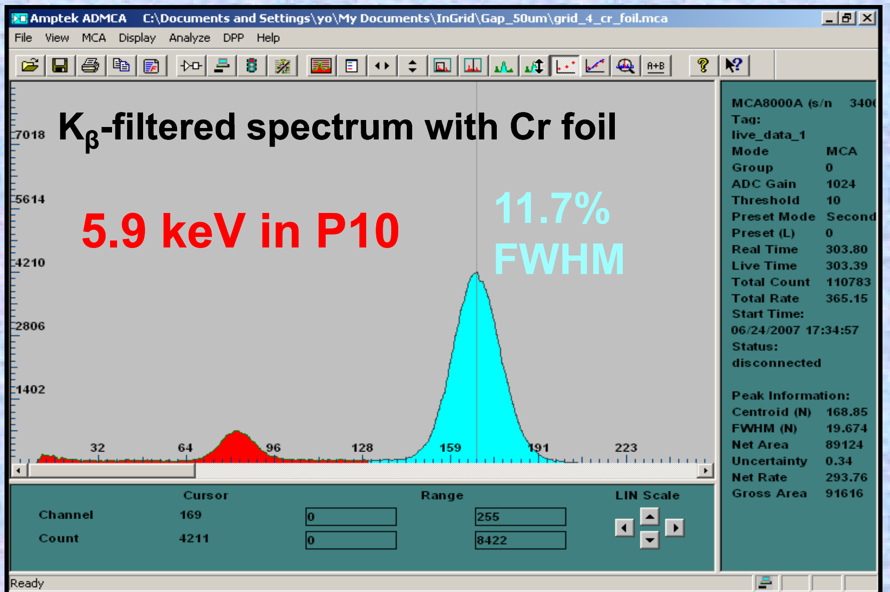
InGrid: NIKHEF-Saclay-CERN-Twente Collaboration

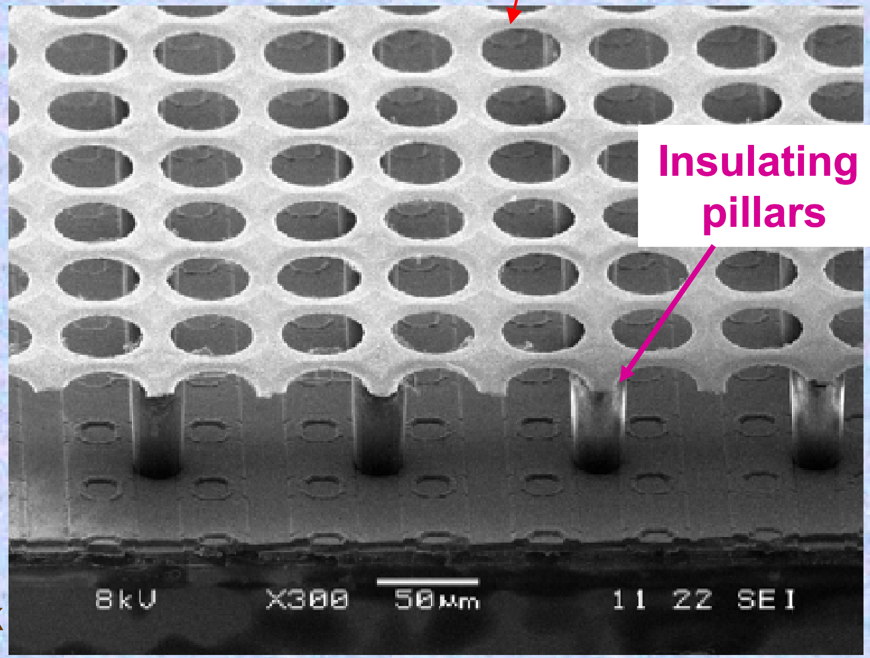
InGrid: integrate Micromegas & Timepix by Si-wafer post-processing technology

- **Grid robustness & Gap/Hole accuracy**



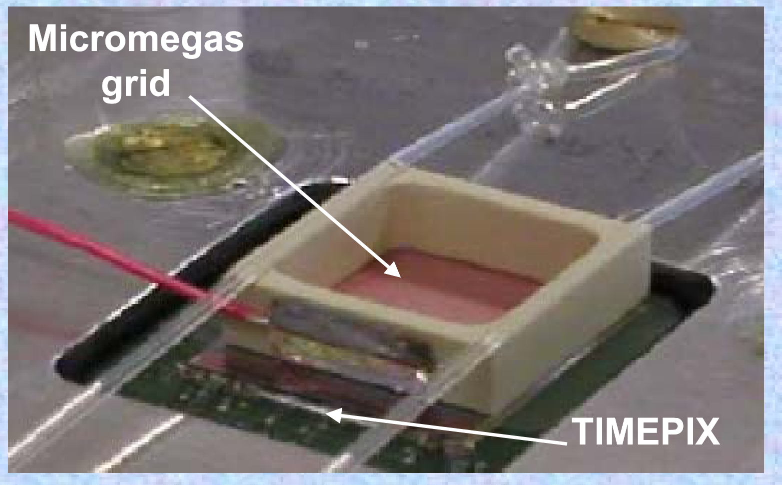






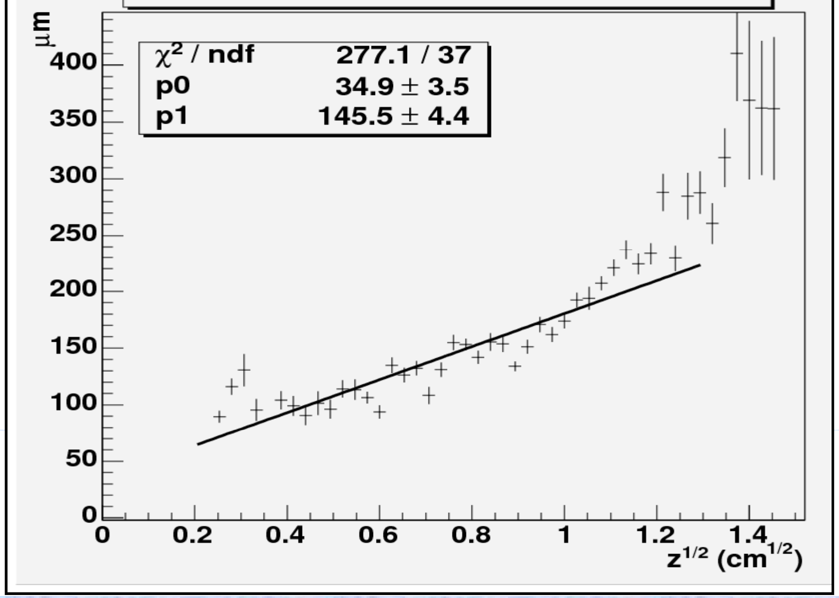
New Grid developments → see J. Timmermans talk

Micromegas and Timepix / MEDIPIX2



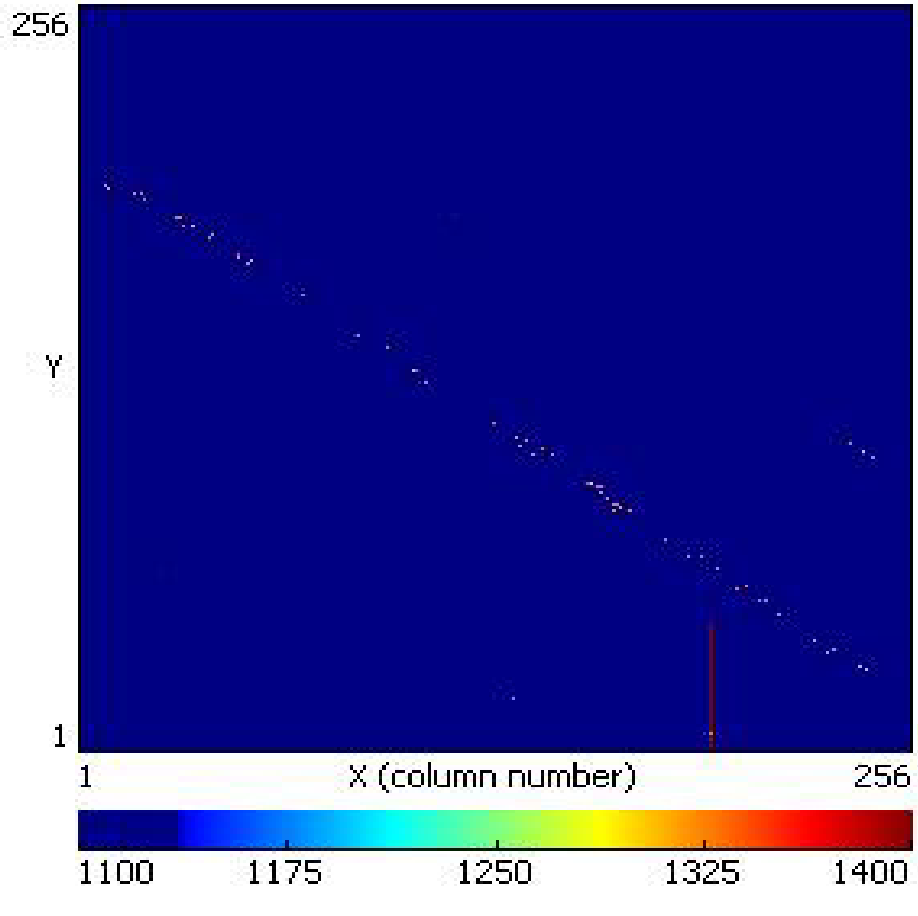
Resolution: $\sigma_t^2 = \sigma_0^2 + D_t^2 . Z$

with σ_0 - resolution at "0" drift length & D_t diffusion coefficient

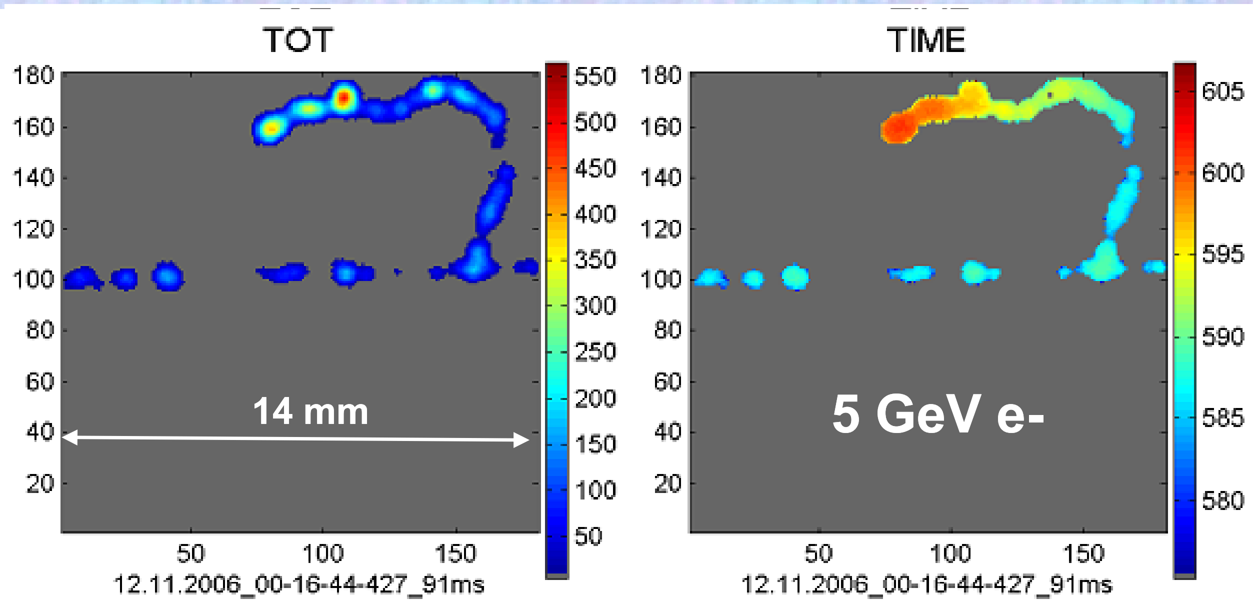


Cosmic ray track:

Timepix + Ingrid + 20 µm thick ASi layer on top of pixel matrix (SiProt)
→ attenuate discharge current

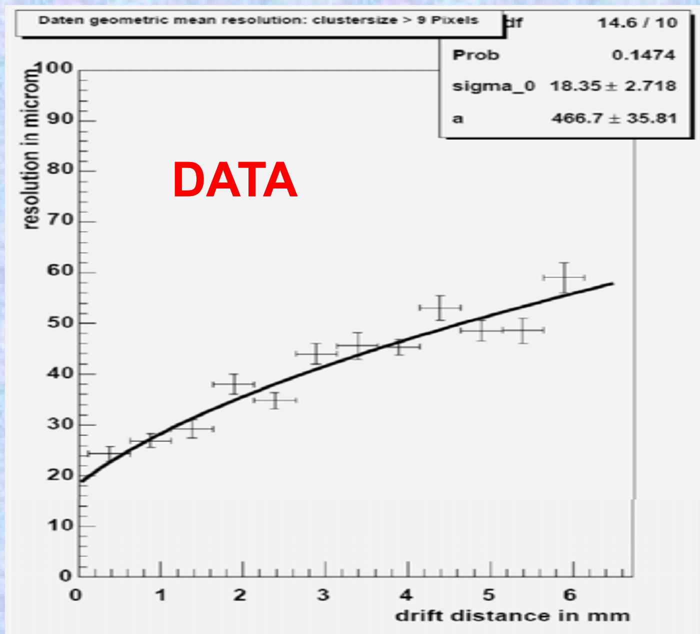


Triple-GEM and Timepix / MEDIPIX2



TIMEPIX CHIP
3D TRACKING (TIME)
+ TOT Information :

- **Superior double track resolution**
- **Benefit from TOT & TIME information (correct timewalk using TOT & reject δ-electrons)**



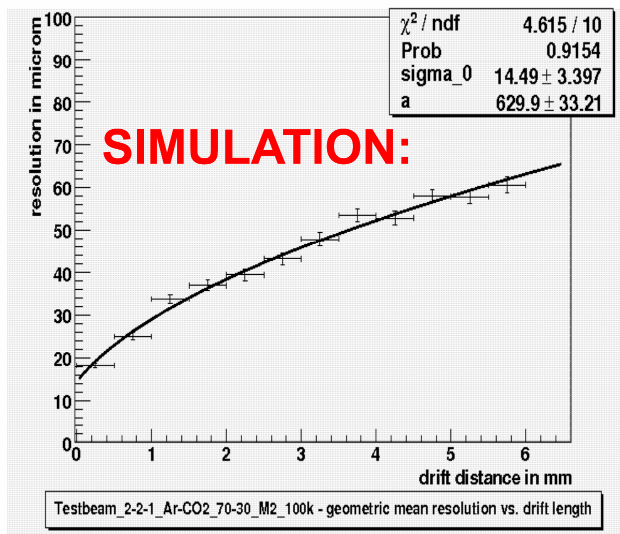
Spatial Resolution vs drift distance:

$$\sigma^2_{mean} = \sigma^2_0 + \frac{D^2_t * z}{n^{el}_{cl}}$$

D_t: transverse diffusion coef.
n^{el}_{cl}: primary electons/ cluster
z: drift distance

$\sigma_0 \sim 20 - 25\ \mu m$

→ See U.Renz talk

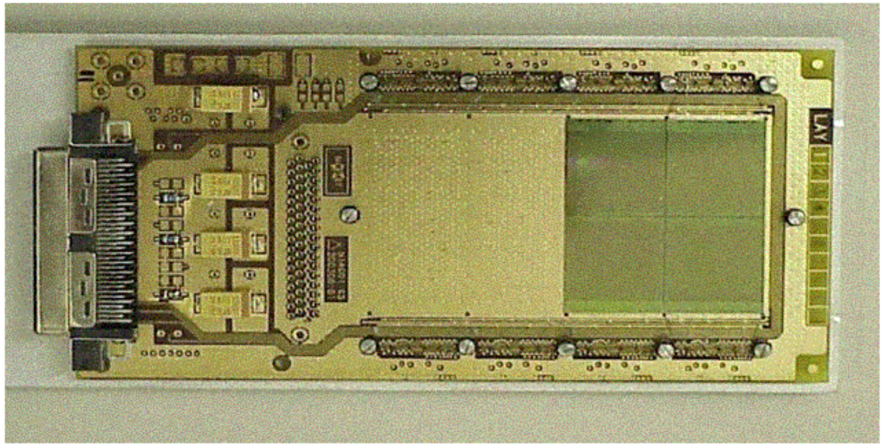


Pixel Readout of Gas Detectors: Future Perspectives

RELAXD project (Dutch/Belgian): NIKHEF, panalytical, IMEC, Canberra

DETECTOR and ELECTRONICS INTEGRATION FOR MILLIONS CHANNELS:

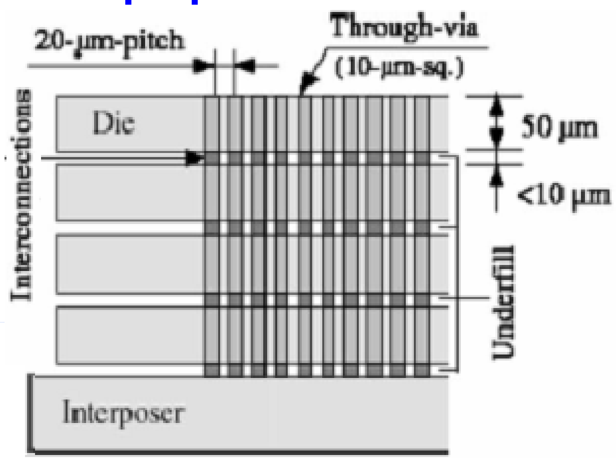
- **Truly 2D / 3D image** (high rate capability)
- **2D high density readout plane** (~50 μm)
- **No long signal routine lines** (low noise)

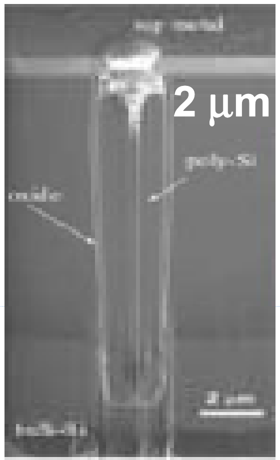


FUTURE DEVELOPMENTS

Avoid bonding wires → 'Through Si-vias'

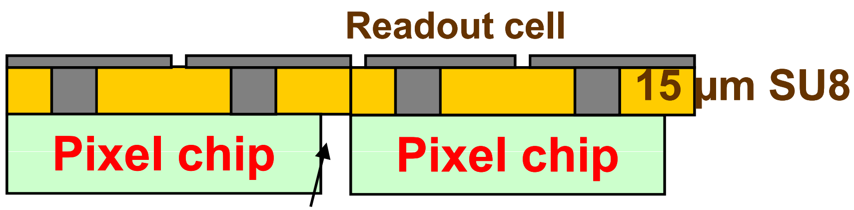
integrated multi-layer pixel chip with `through-wafer vias' connections: perpendicular holes through all Si





Wafer post-processing →

possibility of signal re-routing (when pixel detectors & readout cells do not match



Avoid `dead surface area' between two pixel chips or in a single pixel chip area, used for in-vias I/O electrical connections

E. Heijne, NIMA541 (2005) 274
K. Takahashi et al, Microelectron Rel. 43 (2003) 1267

V. Software Tools Development for the MPGD

Many tools developed to simulate gaseous detector configurations

Maxwell (Ansoft)
Electrical field maps in 2D & 3D

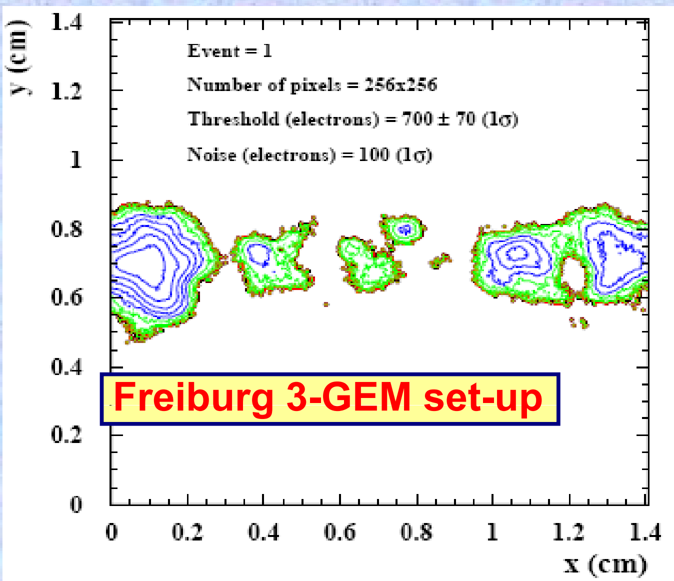
Magboltz (S. Biagi)
Electron transport properties, drift
Diffusion, multiplication, attachment

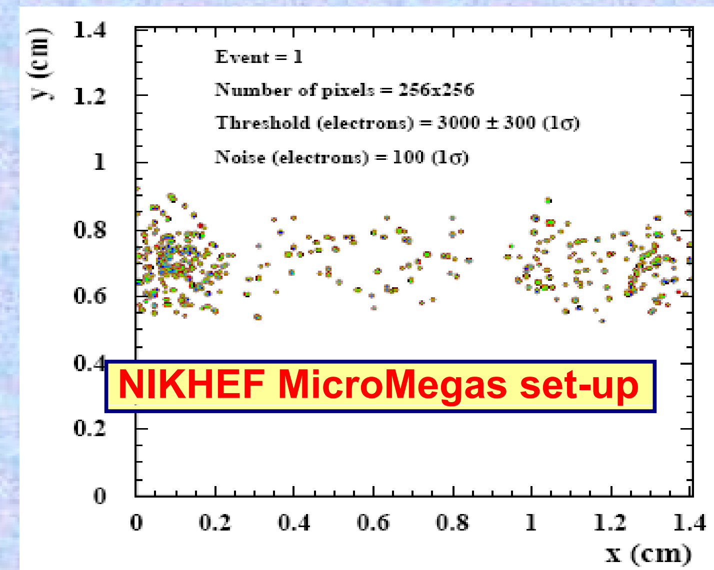
HEED (I. Smirnov)
Energy loss, ionization

Garfield (R. Veenhof)
Electrical field maps in 2D & 3D
fields, drift properties

Software tools → See R. Veenhof and J. Apostolakis talks

SIMULATION STUDIES FOR PIXEL READOUT OF ILC TPC:
(http://hausch.home.cern.ch/hausch/MediPix.html)

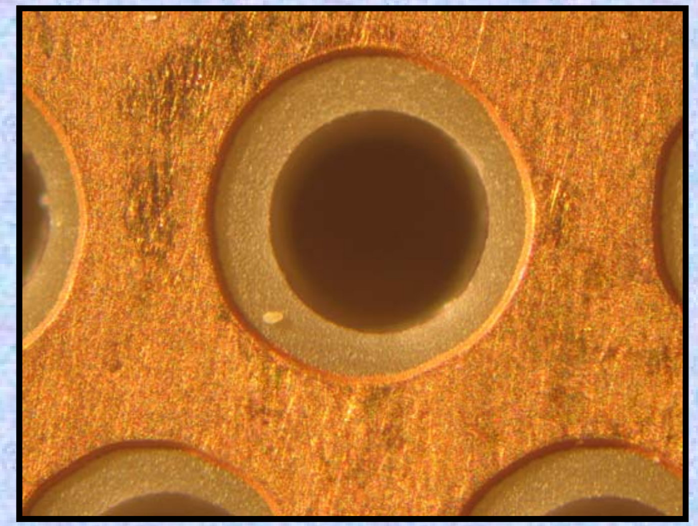




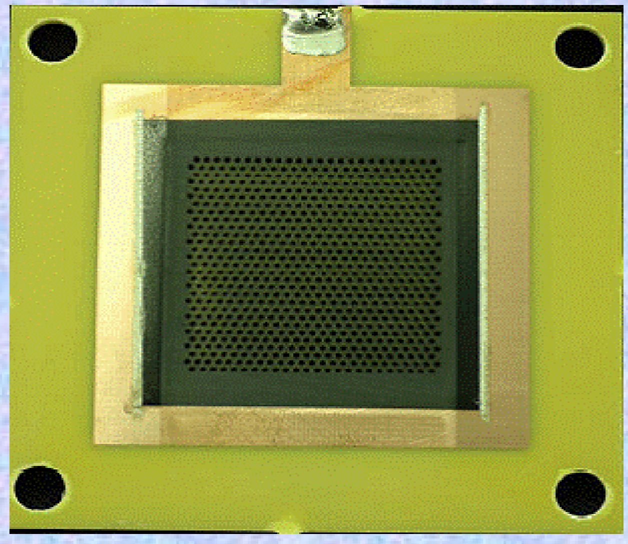
SIMULATED CHARGE DISTRIBUTION ON THE MEDIPIX2 / TIMEPIX SURFACE AFTER 100 cm OF DRIFT (TESLA TDR gas B = 4 T)

VI. Advances in Hole-Type Multipliers (THGEM, RETGEM, MCP) for Photon Detection

Thick-GEM (THGEM)



RETGEM



(see M. Cortesi, V. Peskov. R. Bellazzini talks)

One of exciting applications of GEM / Micromegas with CMOS multi-pixel readout could be position sensitive single photon detection

Thick-GEM Multipliers (TGEM)

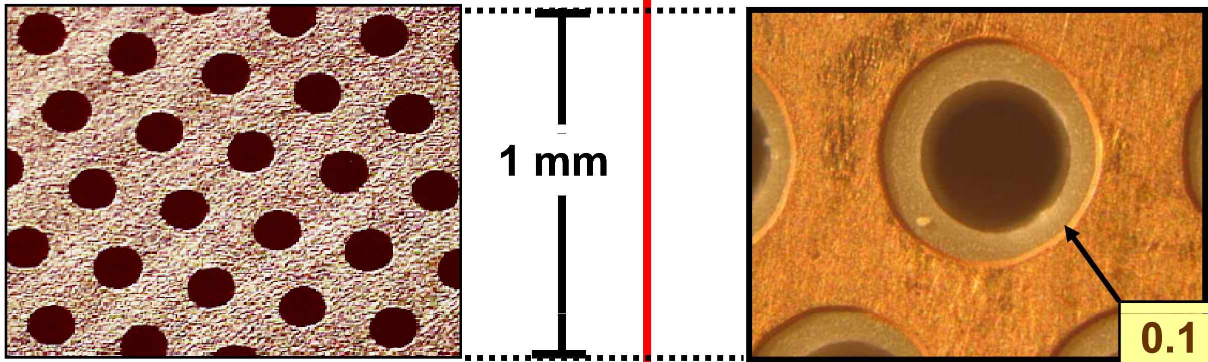
Simple & Robust → Manufactured by standard PCB techniques of precise drilling in G-10 (and other materials) and Cu etching

STANDARD GEM

10^3 GAIN IN SINGLE GEM

THGEM

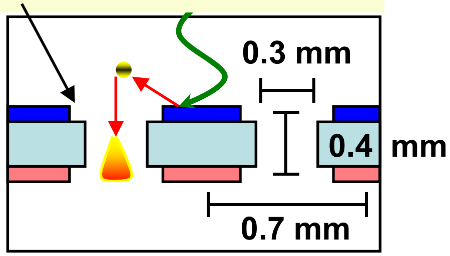
10^5 gain in single-THGEM



0.1 mm rim to prevent discharges

The simplest gas PMT!

Reflective CsI PC



- **BETTER STABILITY**
- **HIGH GAIN (10^6)**

(Advances in THGEM detectors → see M. Cartesi talk)

LARGE-AREA DETECTORS (ns, sub-mm, MHz/mm^2):

Single-photon imaging (e.g.RICH)

Sub-mm Resolution:

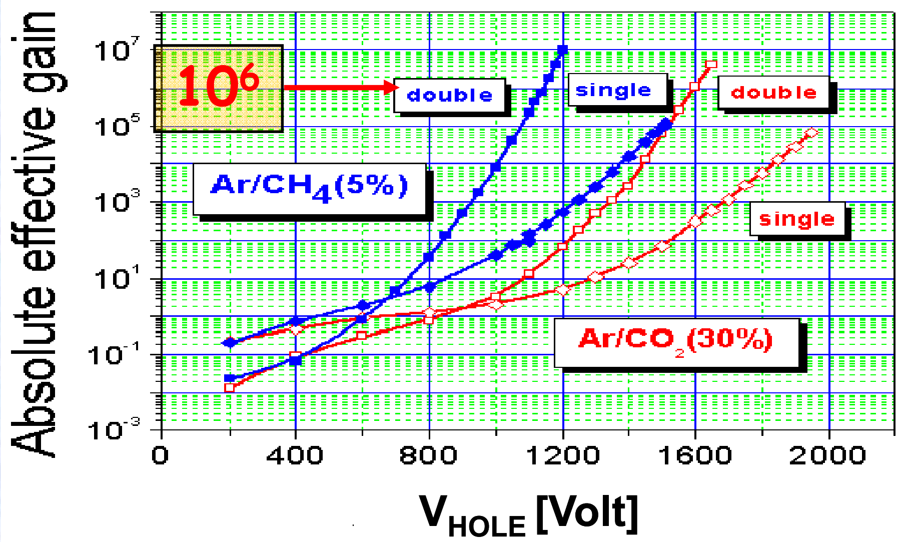
Particle tracking,TPC readout

X-ray & neutron imaging

sampling elements in calorimetry

C. Shalem et al, NIMA558 (2006) 475;

R. Chechik et al, NIM A535 (2004) 303;



Thick GEM with Resistive Electrodes

Spark-protected Resistive Electrode Thick GEM (RETGEM) manufactured by a screen - printing technology

Screen printing is widely used in microelectronics to produce patterns of different shape and resistivity. Therefore, RETGEM technology produced with screen printing techniques offers a convenient and widely available alternative to RETGEMs made of Kapton.

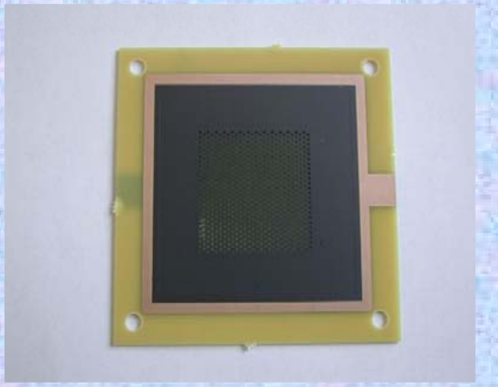
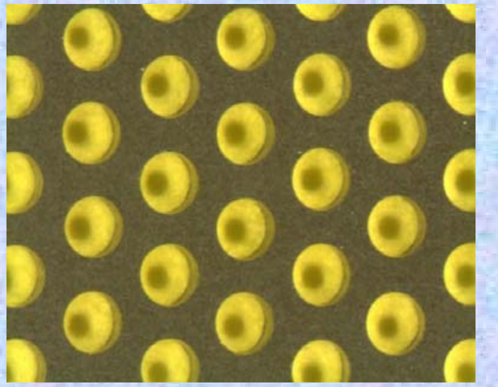
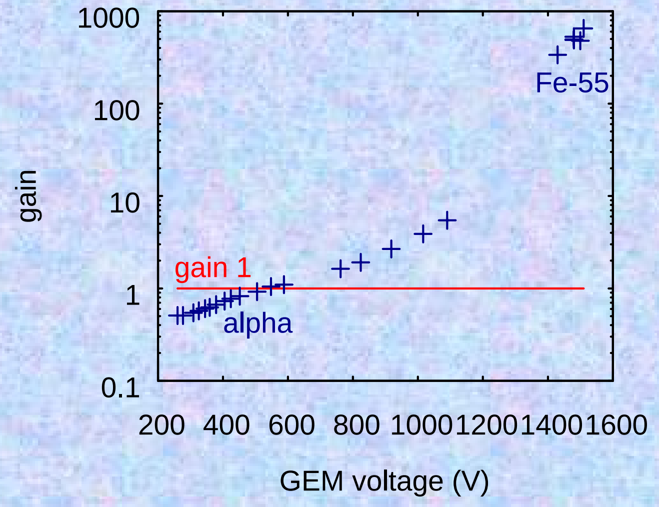


Photo of a new RETGEM



A magnified photo of holes



Gas gain characteristics

Advantages of the screen printing technology:

Offers cost-effectiveness, convenience, and easy optimization RETGEMs resistivity and geometry. Large area RETGEMs can be produced by this technology.

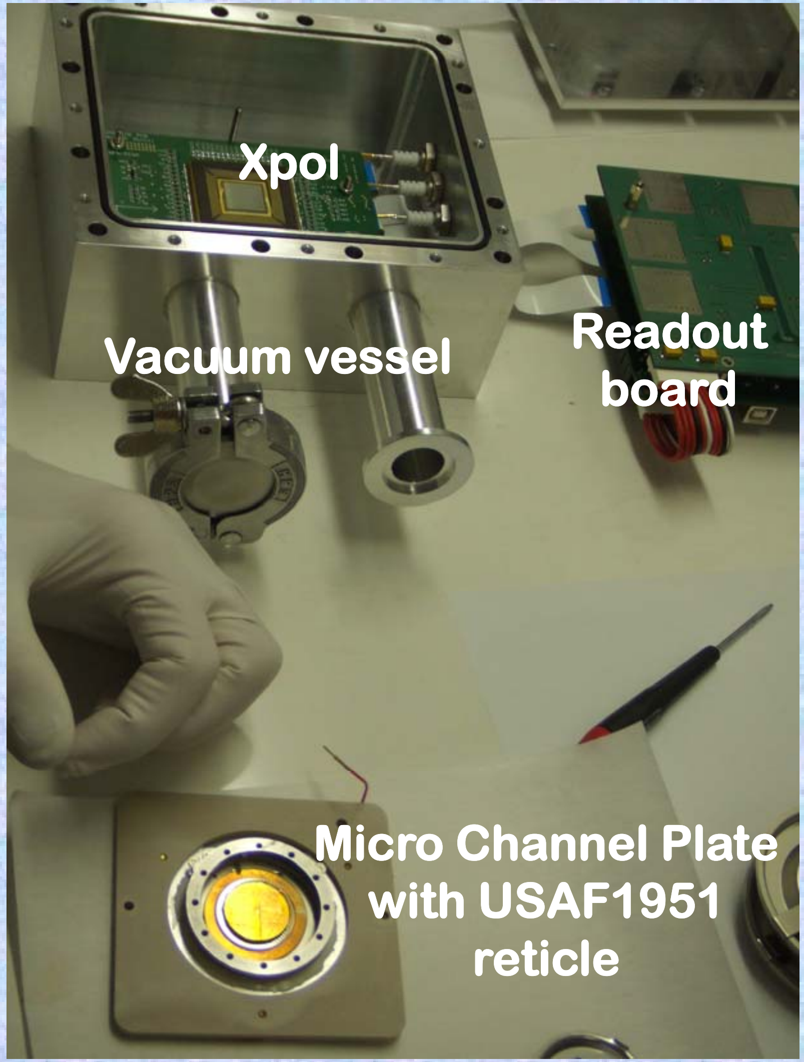
(Advances in RETGEM → see V. Peskov talk)

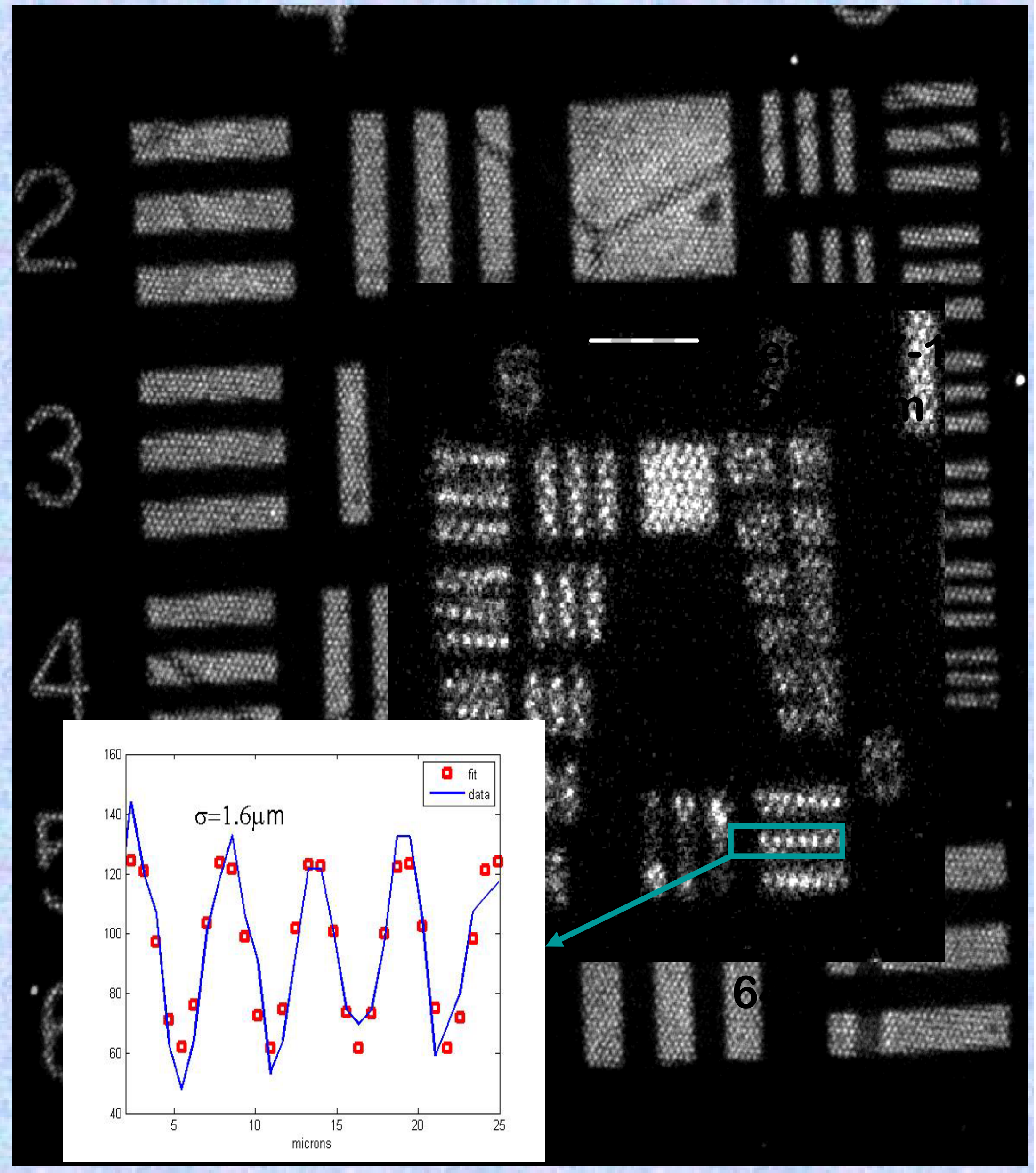
B. Clark et al, physics/0708.2344

MCP + VLSI ASIC @ Space Science laboratory (Berkeley)

MCP (4 μm) hole at 5.5 μm pitch:

RESOLUTION ~ 1- 2 μm





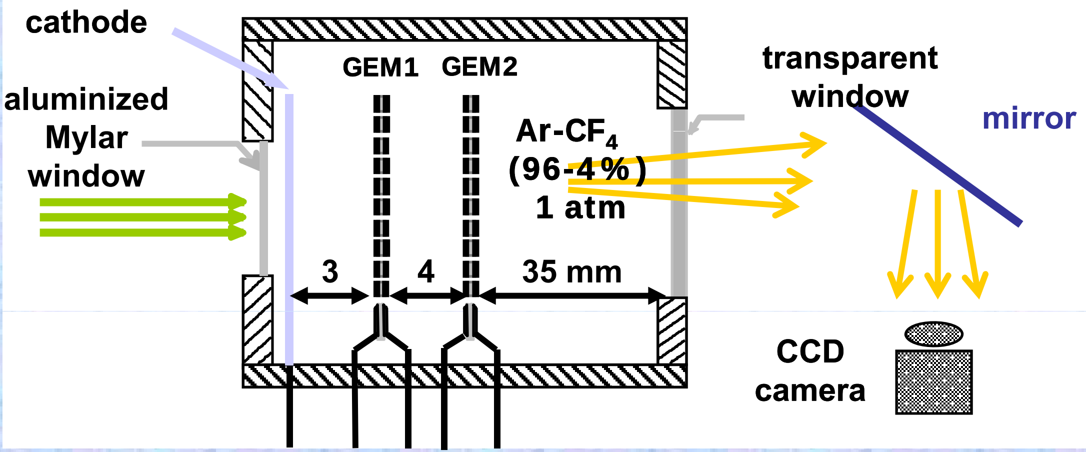
GEM and other charge multipliers with VLSI pixel ASIC → See R. Bellazzini talk

VII. MPGD Industrial Applications (Dose Imaging in Radiotherapy, Portal Imaging Devices)

A real collaboration between research and industrial world will be crucial for future MPGD developments

A Scintillating GEM for Dose Imaging in Radiotherapy

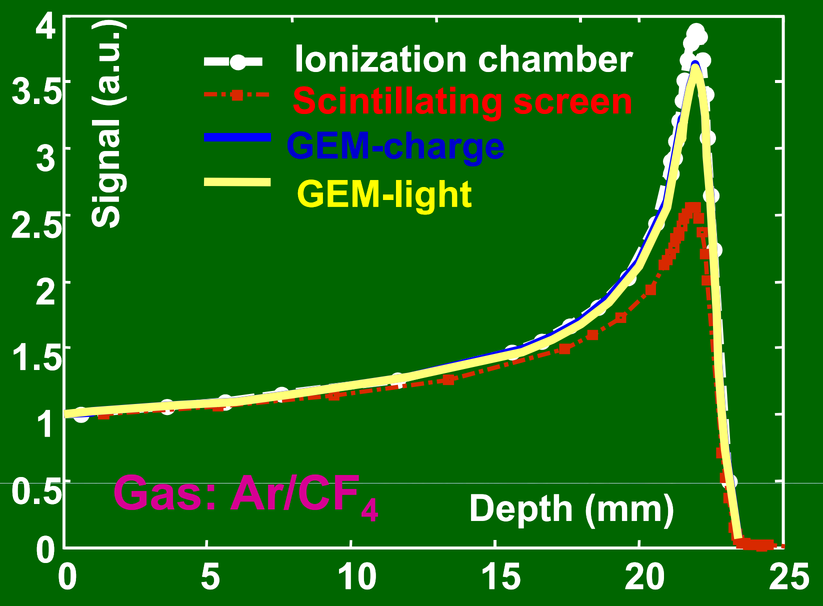
Scintillation light (optical) & charge Readout:



Light output for 138 MeV protons:

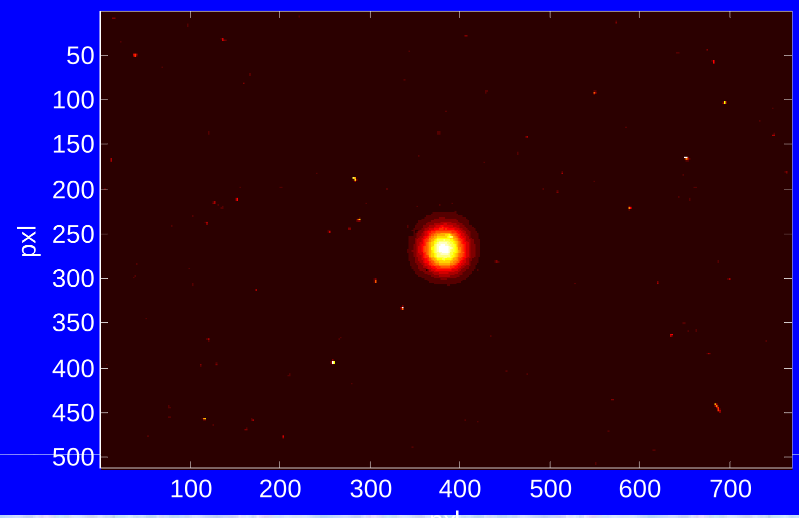
Scintillation type	Gas gain	Light signal (CCD) at 1Gy proton dose (ADU)
Screen (Gd_2O_2S:Tb)		2670
Ar/CO_2 (90:10)	3000	270
Ar/CF_4(90:10)	1400	2350
Ar/CF_4(95:5)	1300	4000
Ar/CF_4(97,5:2,5)	770	2000

Bragg curve with 360 MeV α-beam



LIGHT SIGNAL FROM GEM:

(only 4% smaller than ionization chamber signal)



E. Sevaralli et al., Scintillating GEM for 2D Dosimetry in α-beam, submitted to IEEE TNS

S. Fetal et al., NIMA513 (2003) 42

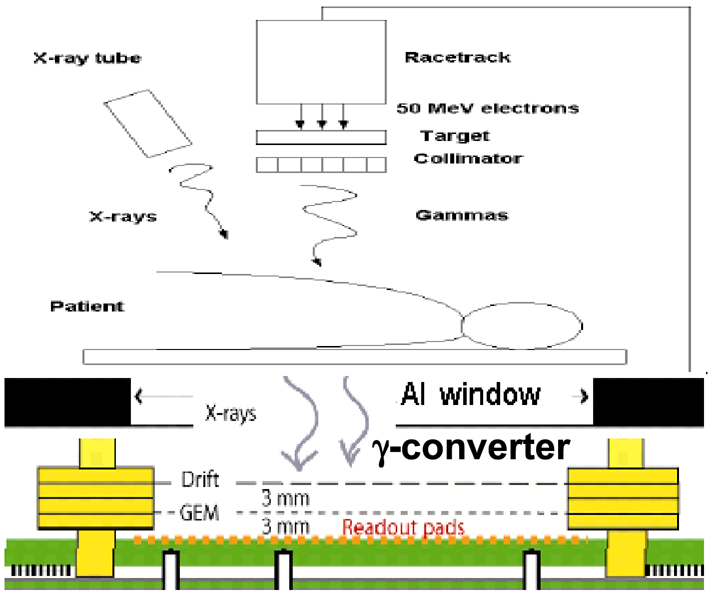
Electronic Portal Imaging Detectors (EPID)

EPID (GEM + γ-Ray Converter):

Cancer treatment pulsed γ-beam
Diagnostic X-ray image of tumor

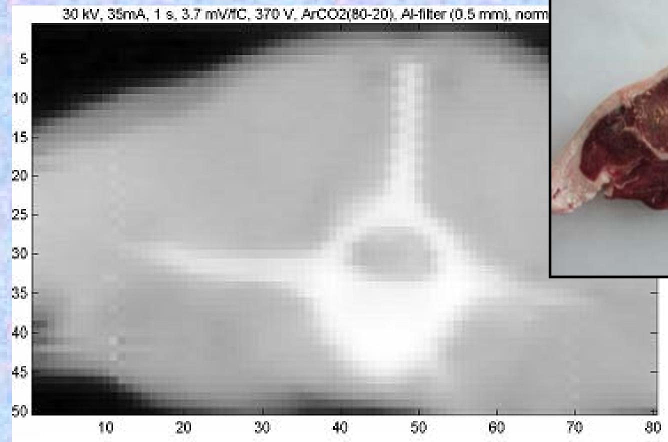
Allow to combine X-ray and γ-ray detector in one device

10^5-10^6 Hz/mm^2 (< 60 keV X-rays);
10^8- 10^9 Hz/mm^2 (< 50 MeV γ-Rays)

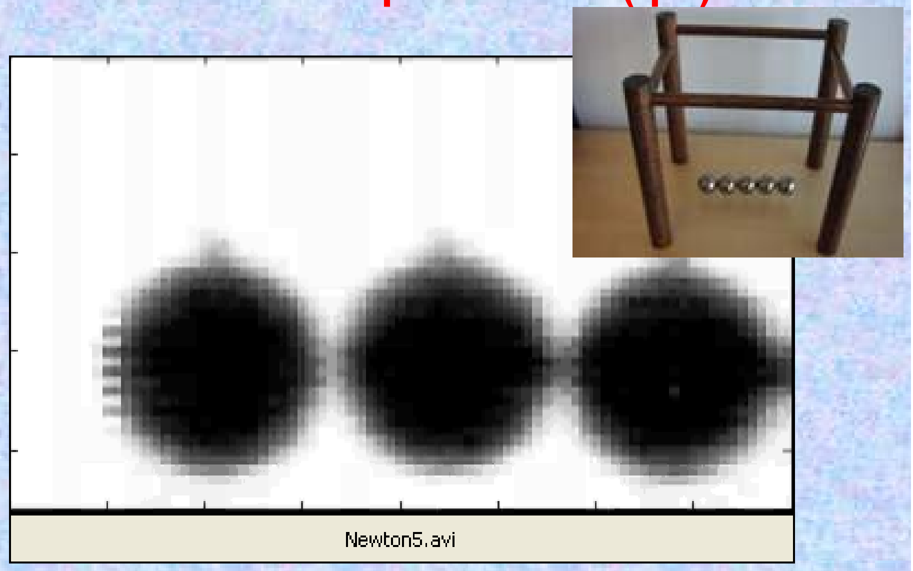


ELECTRONICS OUTSIDE THE BEAM
→ RADIATION TOLERANT DEVICE

X-Ray (30 keV): Lamb chop (thickness 15 mm)

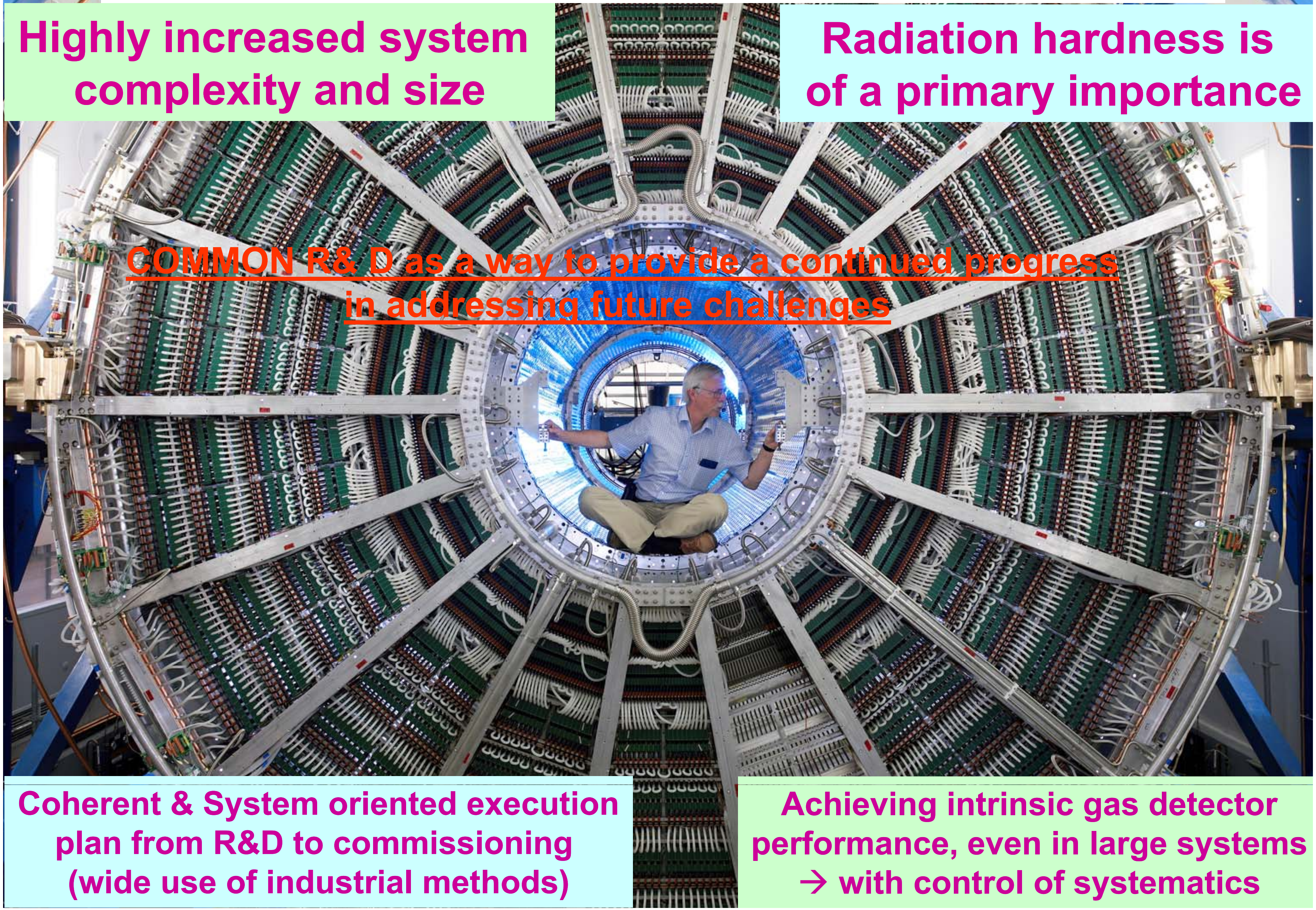


Newtonian demonstrator: X-Rays (< 40 keV)
→ 70 frames per second (fps)



J. Ostling et al. IEEE TNS-50 (4) (2003) 809
J. Ostling et al, NIMA525(2004) 308

Challenges for Future Detector Development in HEP



Highly increased system complexity and size

Radiation hardness is of a primary importance

COMMON R& D as a way to provide a continued progress in addressing future challenges

Coherent & System oriented execution plan from R&D to commissioning (wide use of industrial methods)

Achieving intrinsic gas detector performance, even in large systems → with control of systematics