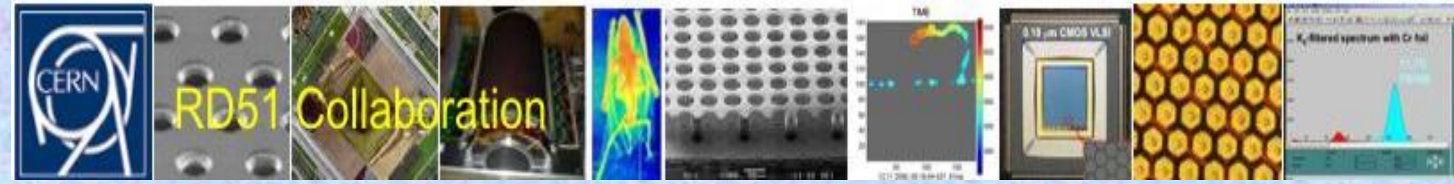
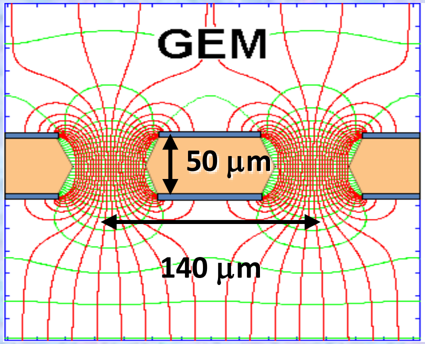
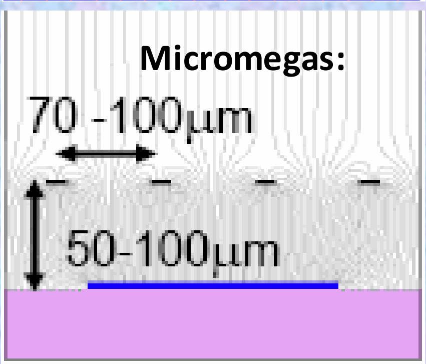
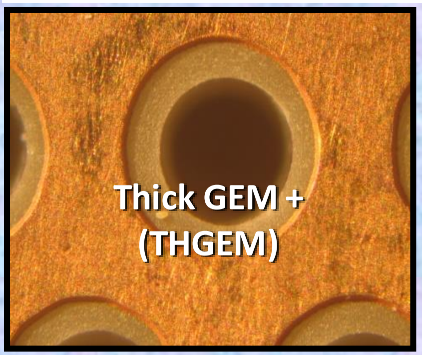


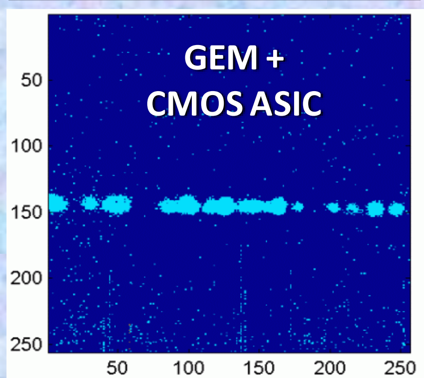
Review of the RD51 (MPGD) activities relevant to the LC Detector R&D

Maxim Titov, CEA Saclay, France









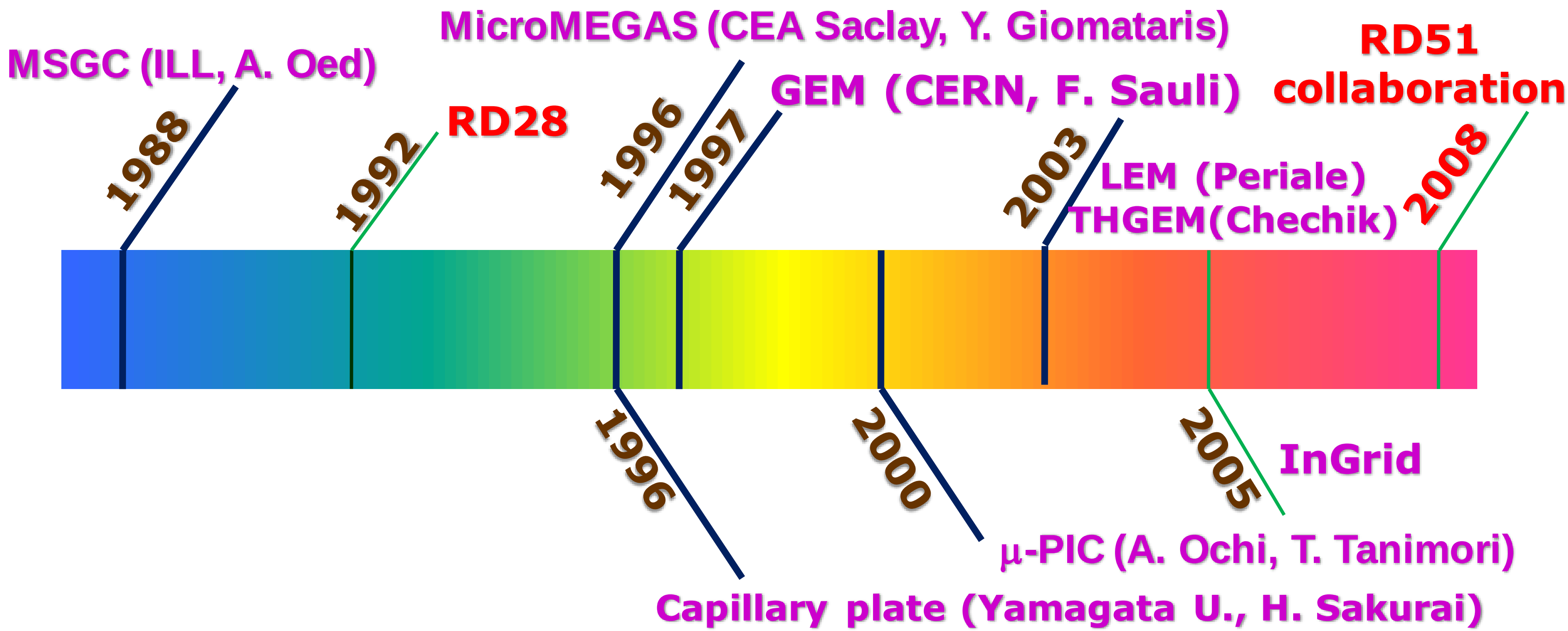
OUTLINE:

- RD51 Introduction and Main Objectives
- RD51 Collaboration Activities
  (Large area MPGD developments, Software & Simulation, SRS Electronics and SRS Lab-Equipment for MPGDs, Production and Industrialization, RD51 Test Beam Facility)
- Future RD51 Activities: Outlook

European Linear Collider Workshop (ECFA LC 2013),
DESY, Hamburg, Germany, May 27 - 31, 2013

MPGD Developments: Historical Roadmap and RD51

(*Many more micro-pattern structures were developed; only widely spread technologies are shown)

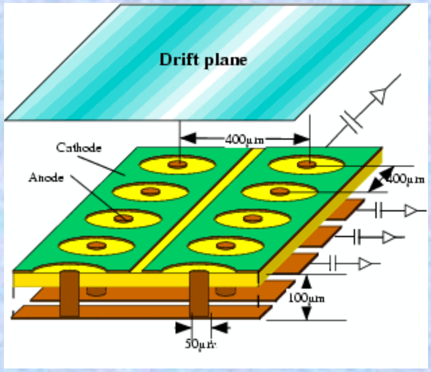


From A.Ochi ADA2012@Kolkata (updated)

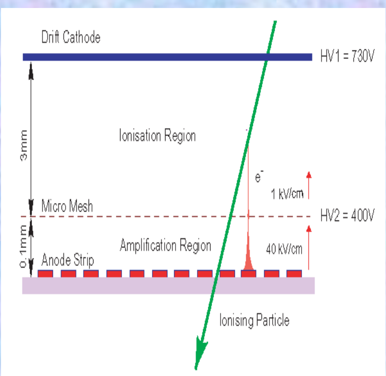
Micro-Pattern Gaseous Detectors: Technologies for Future Projects

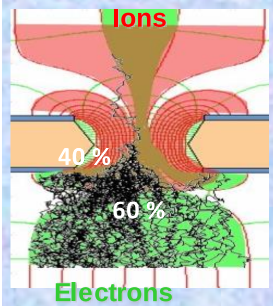
- **Micromegas**
- **GEM**
- **Thick-GEM, Hole-Type Detectors and RETGEM**
- **MPDG with CMOS pixel ASICs ("InGrid")**
- **Micro-Pixel Chamber (μPIC)**

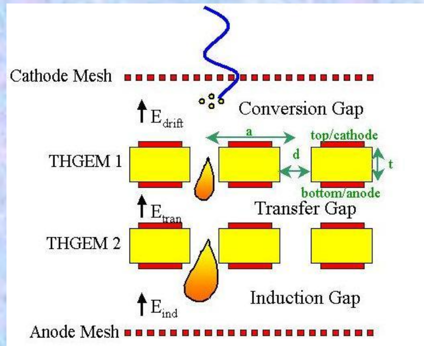
μ PIC

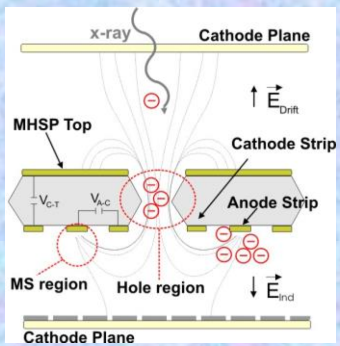


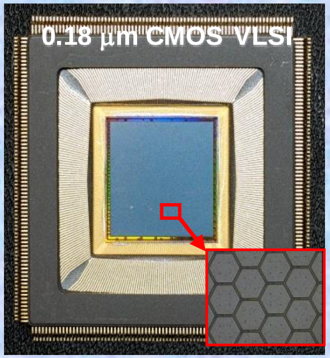
CMOS high density readout electronics

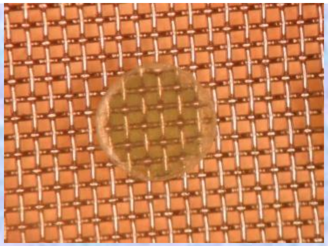




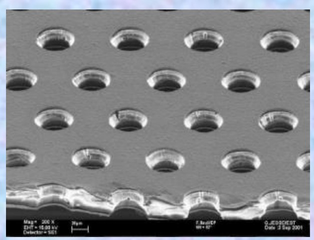




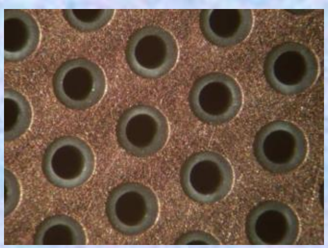




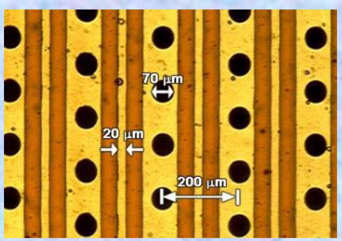
Micromegas



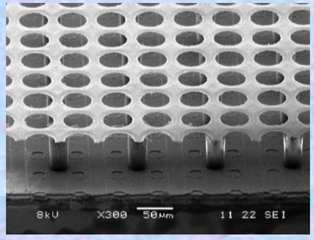
GEM



THGEM



MHSP



Ingrid

RD51 Collaboration: "Development of MPGD Technologies"

The main objective of the R&D programme is to advance <u>technological development</u> of Micropattern Gas Detectors

- <u>~ 85 institutes</u>
- <u>~ 450 people involved</u>
- Representation (Europe, North America, Asia, South America, Africa)

MPGD2011, the first conference in the international series in Asia

Kobe, Japan, September 2011

"RD51 aims at facilitating the <u>development of advanced gas-avalanche detector technologies</u> and associated electronic-readout systems, <u>for applications in basic and applied research</u>"

RD51 contributes to the LHC upgrades, BUT,
<u>the most important is:</u>
RD51 serves as an access point to MPGD "know-how" for the world-wide community

Bari, Italy, October 2010

RD 51 Collaboration - Working Groups

"Transverse organization" of MPGD activities in 7 Working Groups

RD51 – Micropattern Gas Detectors

http://rd51-public.web.cern.ch/RD51-Public

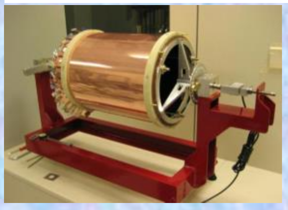
	WG1 MPGD Technology & New Structures	WG2 Characterization	WG3 Applications	WG4 Software & Simulation	WG5 Electronics	WG6 Production	WG7 Common Test Facilities
Objectives	Design optimization Development of new geometries and techniques	Common test standards Characterization and understanding of physical phenomena in MPGD	Evaluation and optimization for specific applications	Development of common software and documentation for MPGD simulations	Readout electronics optimization and integration with MPGD detectors	Development of cost-effective technologies and industrialization	Sharing of common infrastructure for detector characterization
Tasks	Large Area MPGDs Design Optimization New Geometries Fabrication Development of Rad-Hard Detectors Development of Portable Detectors	Common Test Standards Discharge Protection Ageing & Radiation Hardness Charging up and Rate Capability Study of Avalanche Statistics	Tracking and Triggering Photon Detection Calorimetry Cryogenic Detectors X-Ray and Neutron Imaging Astroparticle Physics Appl. Medical Applications Synchrotron Rad. Plasma Diagn. Homeland Sec.	Algorithms Simulation Improvements Common Platform (Root, Geant4) Electronics Modeling	FE electronics requirements definition General Purpose Pixel Chip Large Area Systems with Pixel Readout Portable Multi-Channel System Discharge Protection Strategies	Common Production Facility Industrialization Collaboration with Industrial Partners	Testbeam Facility Irradiation Facility

RD 51 Collaboration Organization

Consolidation around common projects: large area MPGD R&D, CERN/MPGD production facility, common electronics developments, software tools, beam tests

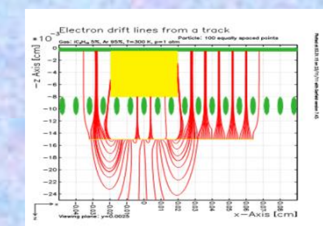
WG1:

Large area (MM, GEM, THGEM)
Design optimization
(e.g. THGEM, Resistive MM)



WG2:

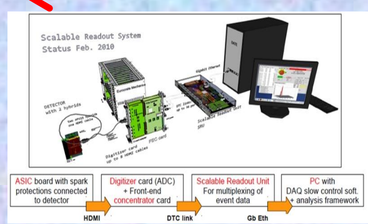
"RD51 Common Projects"
(Generic R&D)



RD51

WG5:

MPGD SRS
Electronics



WG4:

Software and
Simulation

WG7:

RD51 Common
Test Beam Facility

WG6:

CERN MPGD Workshop
& Industrialization

Summary of the RD51 Activities and Achievements

❖ Consolidation of the Collaboration and MPGD Community Integration (> 80 institutes, 450 members);

❖ Major progress in MPGD Technologies: Large area GEM (single mask), Micromegas (resistive) and THGEM; picked up by experiments, including LHC upgrades;

❖ Secured future of the MPGD Technologies development through the TE MPE workshop upgrade and FP7 AIDA contribution

❖ Contacts with industry for large volume production; MPGD industrialization and first industrial runs

❖ Major improvement to the MPGD simulation software framework for small-scale structures for applications;

❖ Development of common, scalable readout electronics (SRS); many developers and > 50 user groups; Production (PRISMA company and availability through CERN store); Industrialization (re-design of SRS in ATCA in EISYS)

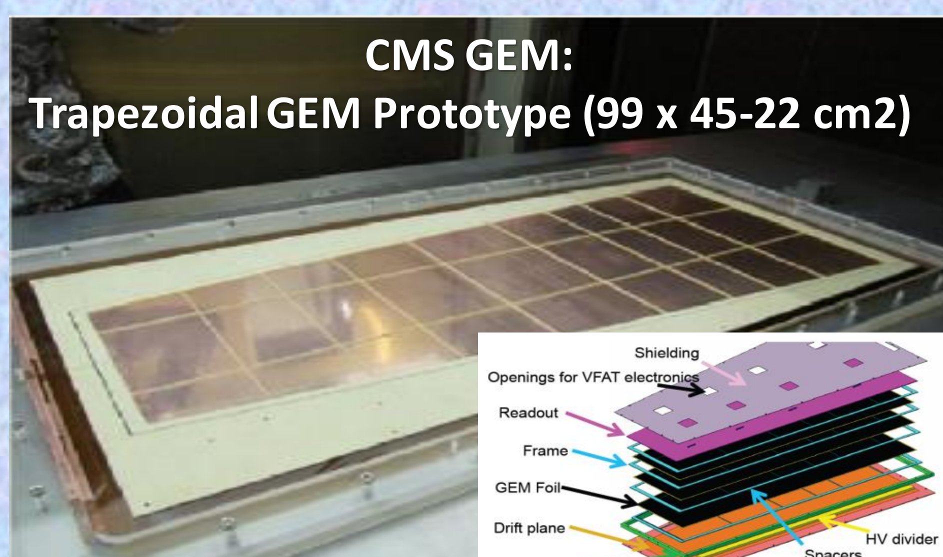
❖ Infrastructure for common RD51 test beam and facilities (> 20 user groups);

MPGD Technologies for Energy Frontier (sLHC, LC)

Ongoing R&D Projects using MPGDs in the framework of HEP Experiments

	Vertex	Inner Tracker	PID/ photo-det.	EM CALO	HAD CALO	MUON Track	MUON Trigger
ATLAS	GOSSIP /InGrid	GOSSIP /InGrid				Micromegas	Micromegas
CMS						GEM	GEM
ALICE		TPC (GEM)	VHPMID (CsI-THGEM)				
Linear Collider		TPC(MM, GEM, InGrid)			DHCAL (MM,GEM, THGEM)		

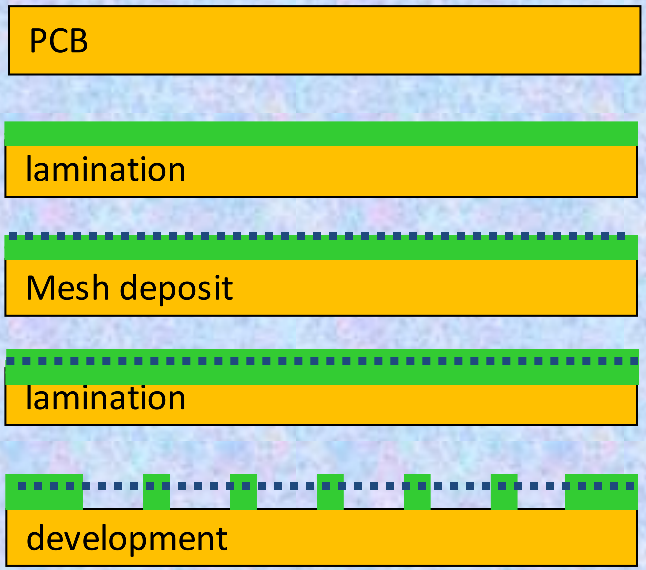
ATLAS Micromegas:
On a road to large-area detectors:
(1.2 * 0.6 m²)

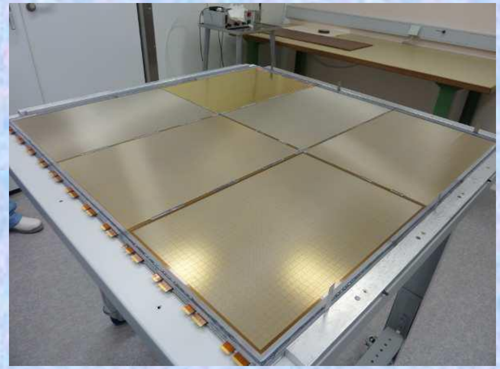


CMS GEM:
Trapezoidal GEM Prototype (99 x 45-22 cm2)

WG1: Large Area Detectors – "Bulk Micromegas" Technology

Bulk Micromegas:





ILC DHCAL (Large area MM 1m^2 prototype: (6 Bulk of 32 *48 cm^2)

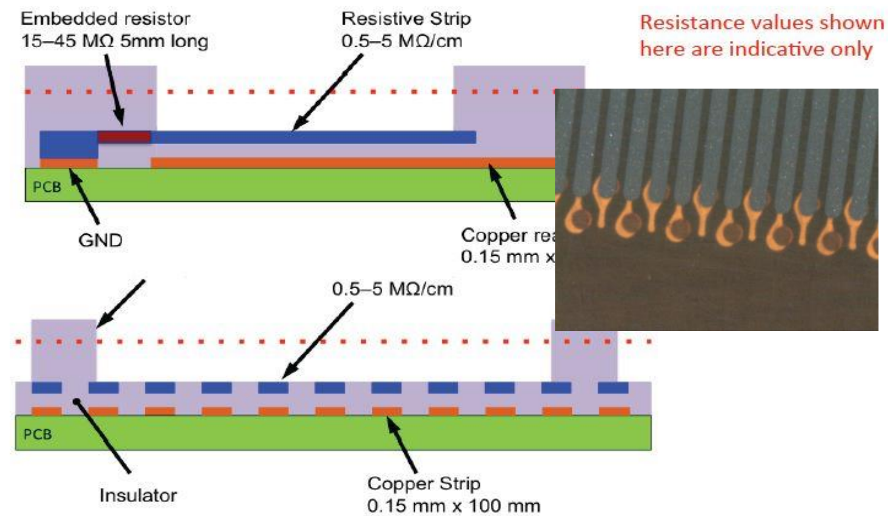
ATLAS MAMMA (2.2 * 0.9 m^2)

Since 2010: "Resistive Bulk Micromegas" Technology

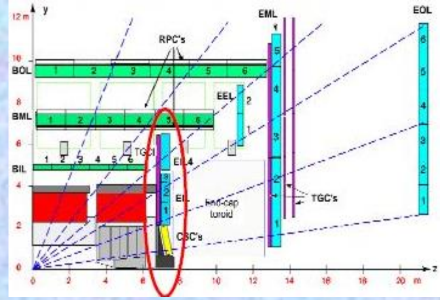
- **Spark neutralization and/or suppression**
- **Resistive strip parallel to readout strips**

Uniformity, robustness, easy fabrication, large area detectors & small dead area→ "Full path of industrial production"

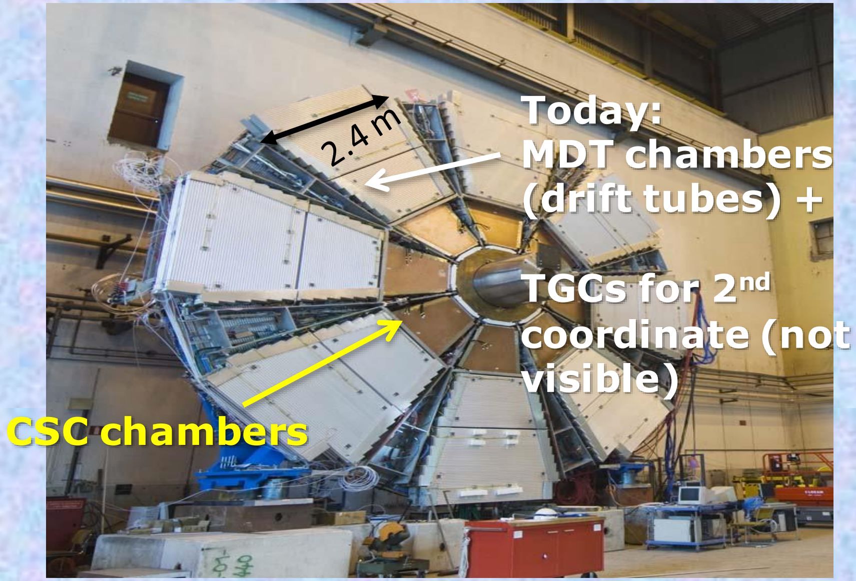
The resistive-strip protection concept



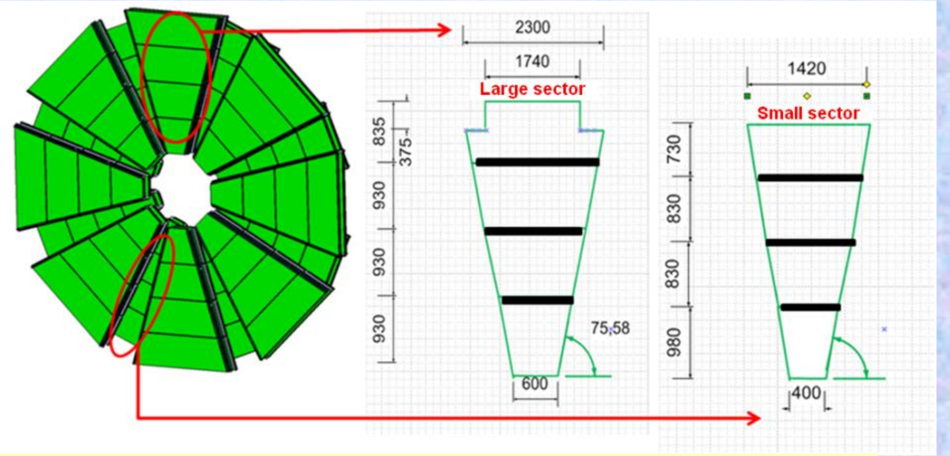
Resistive MM for the ATLAS Muon System Upgrade



Resistive strip Micromegas has been chosen as the baseline option for the upgrade of the ATLAS Small Wheel:



Combine precision and 2nd coordinate meas. and trigger functionality in a single device



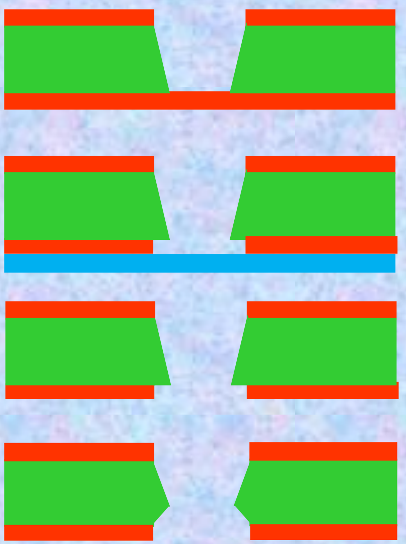
Equip Small Wheels with 128 MM (0.5–2.5 m²): ~ 1200 m² of resistive MM

Sector	Nbr sectors Nbr chambers/sector MM layers/chambers	MM layer area (containing rectangle)	Total Nbr MM layers (w/o spares)	Total MM PCB area	Manufacturing plan (preliminary)
Small	8x2=16 4 4x2=8	From ~0.68m² (696x980) To ~1m² (1420x730)	512	0.88x512 = 450m²	Yrs 2015 +2016
Large	8x2=16 4 4x2=8	From ~0.96m² (1036X930) To ~1.9m² (2300x835)	512	1.5x512= 768m²	Yrs 2015 +2016

Price could go down to 2000 CHF/m² for large-volume MM & PCB production (Rui de Oliveira)

WG1: Large Area Detectors – Single Mask GEM Technology

Since 2009: Single Mask GEM:

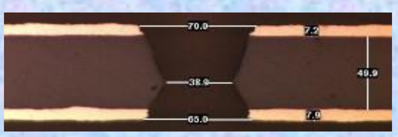


Chemical Polyimide etching

Copper electro etching

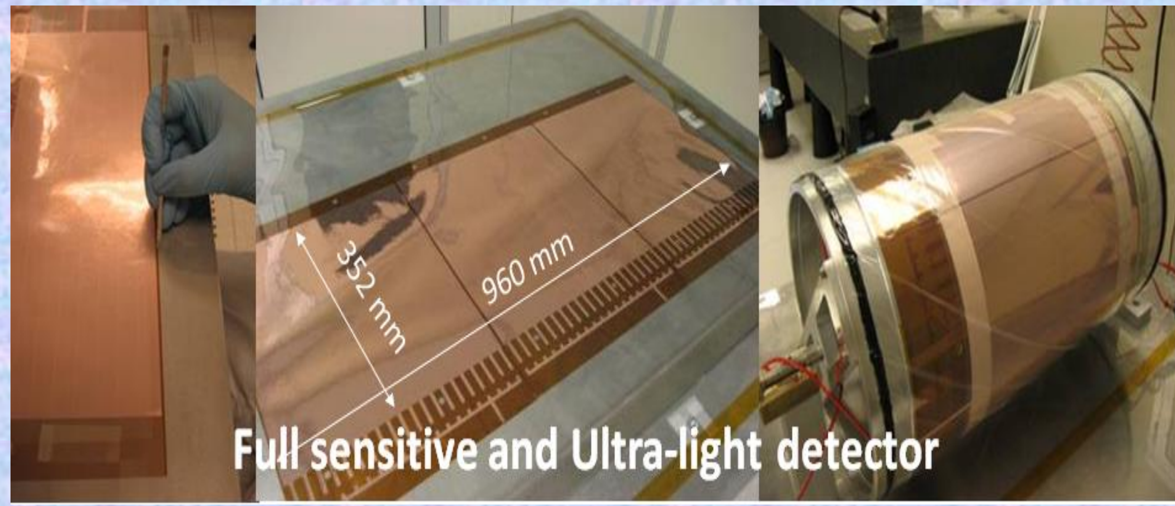
Stripping

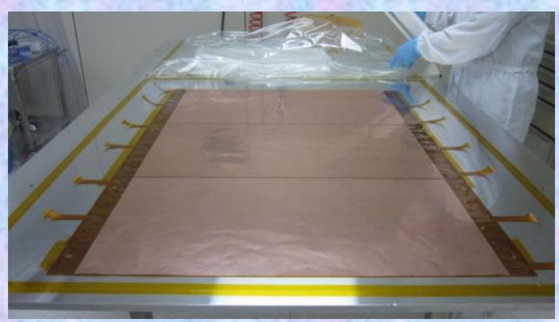
Second Polyimide etching

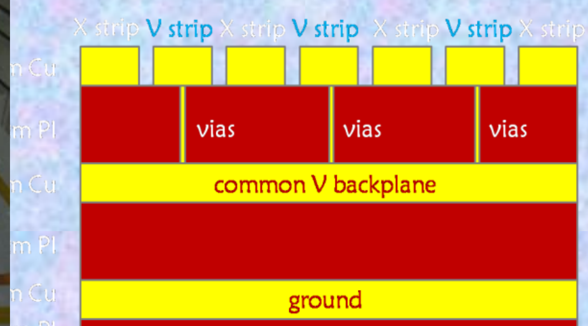


Result

Large Area Cylindrical GEM Detectors for KLOE2 Tracker:



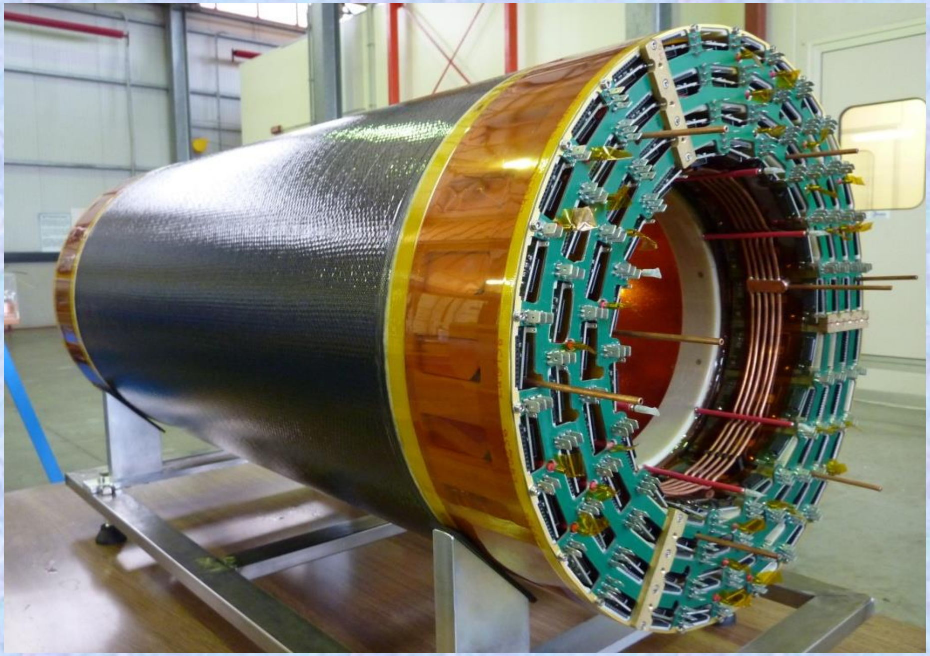




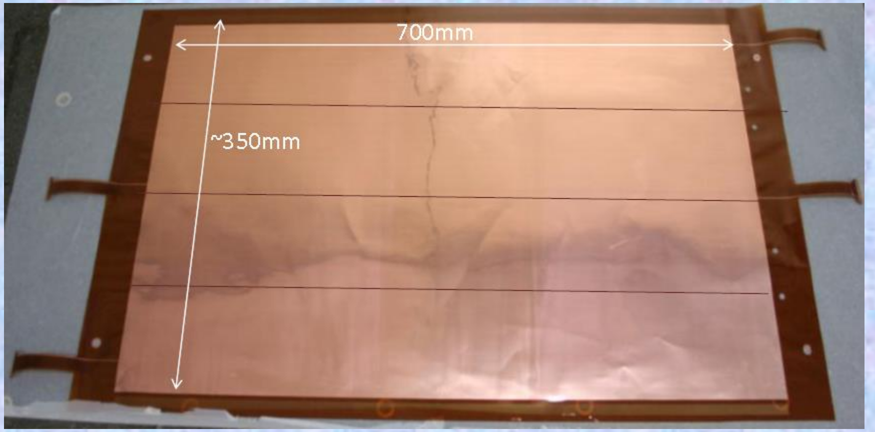
The readout is a multilayer flexible circuit on a polyimide substrate providing a 2-dim point with XV strips at 650 μm pitch

The Final Assembly of the KLOE-2 Inner Tracker

The first cylindrical GEM detector ever built (April 2013):



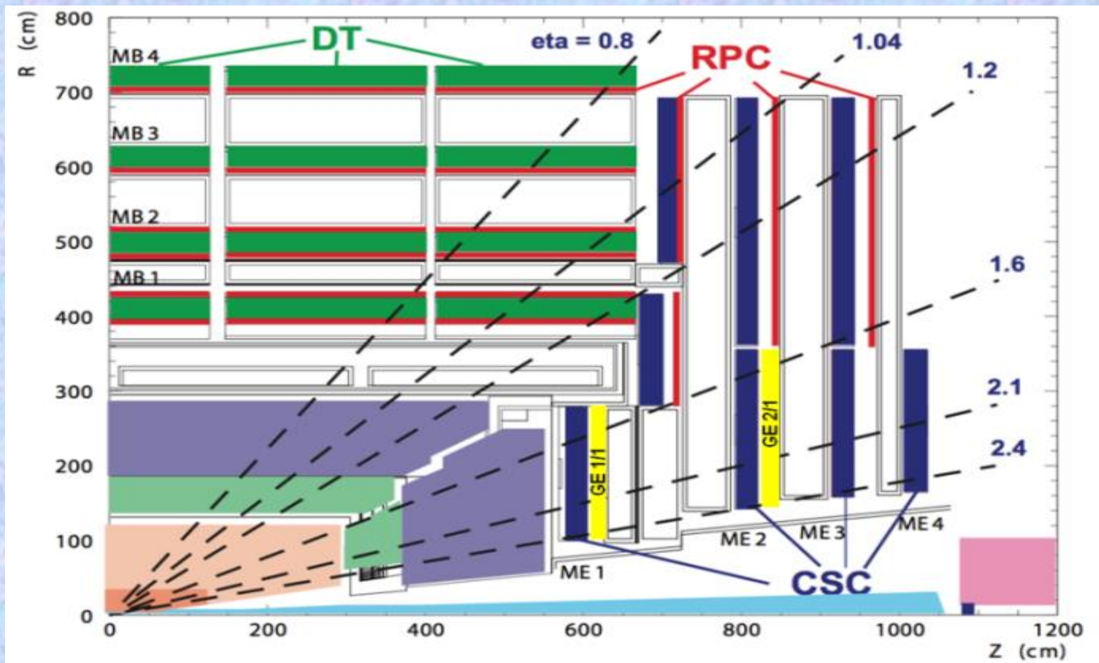
Summary of KLOE-2 QA Procedures
(D. Domenici, RD51 Mini-week , April 2013)

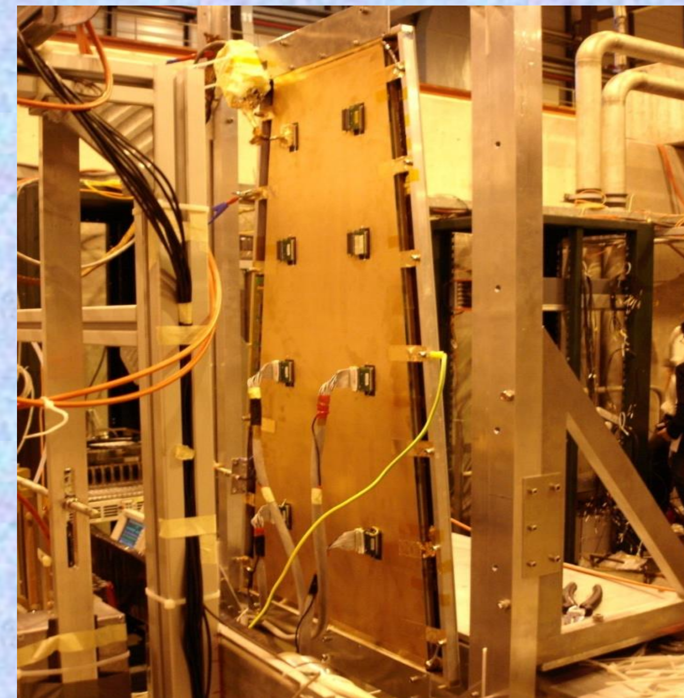


- 50 GEM foil total
- 38 (76%) GEM foils OK
  - 5 of them recovered after Rui's washing
- 12 (24%) GEM foils BAD
  - 8 problems in active area: 3 current leak, 1 short, 3 continuously discharging, 1 rough defined sector edge
  - 4 external problems: 3 high resistance HV vias, 1 damaged HV tails

GEMs for CMS High Eta Project (1.6 > η > 2.1)

CMS Muon Upgrade with GEMs in high-η Region → proceed to TDR in July 2013:





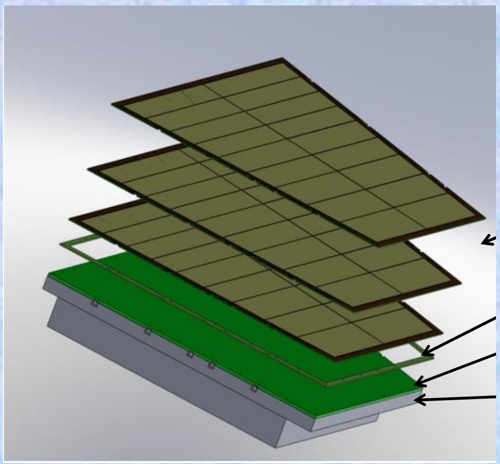
Targeted for the LS2 Shutdown:
About 1000 m^2 ; 216 triple-GEM detectors

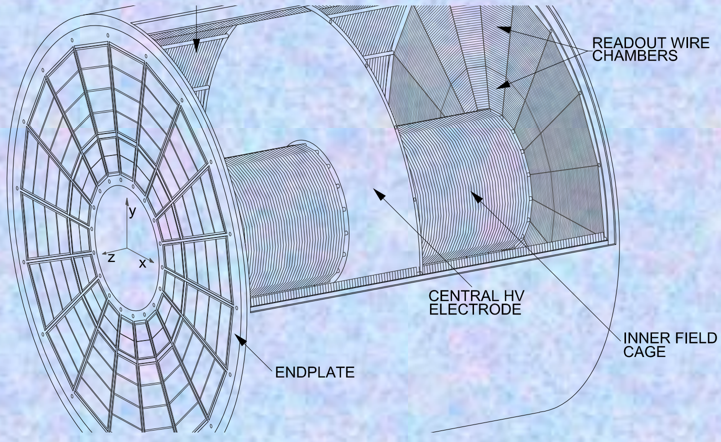
Development of self-stretching technique:
assembly time reduction from 3 days → 2 hours

Station	Nbr of modules	Module area (containing rectangle)	Total Nbr of modules (w/o spares)	Total GEM foil area (3ple GEMs)	Manufacturing plan (preliminary)
1	18x2x2=72	~0.43m^2 (440x990)	72	0.43x72x3= 93m^2	Yrs 2014+2015
2	36x2=72 (long) 36x2=72 (short)	~2.4m^2 (1251x1911) ~1.6m^2 (1251x1281)	144	(2.4+1.6)x72x3= 864m^2	Yrs 2015+1016

ALICE Upgrade: TPC Endplate with GEMs

See yesterday's talk → M. Ball, ALICE TPC Update





Total area: 32.5 m²

detector sizes from: 46 x 50 cm² to 88 x 112 cm²

→Use single-mask GEM technology

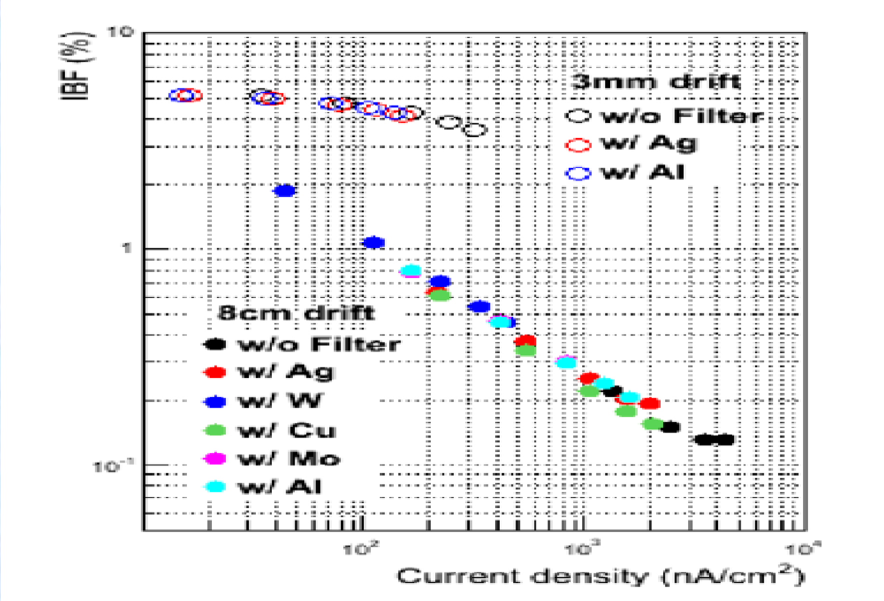
Goals and Requirements:

❖ **Replace MWPC with GEMs** (Space-charge effects at 50 kHz Pb-Pb continuous readout too high with wires)

❖ Limit GEM **ion back-flow to 0.25%** at gain 1500 (major R&D required)

❖ Maintain **excellent dE/dx resolution** for particle Id **and time stability**

IBF – Rate Dependency:



MPGD Readout Structures for the ILC TPC

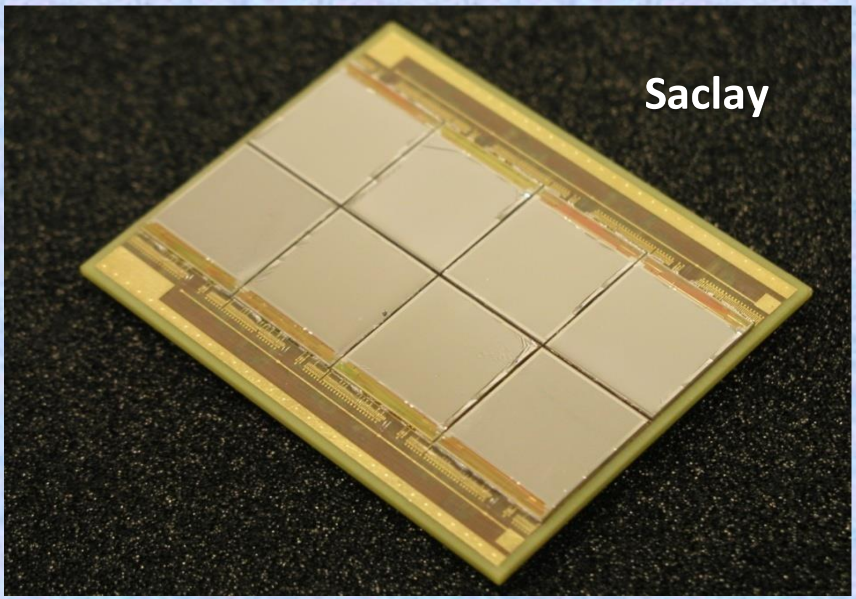
Readout		Pad Size & Electronics	Detector Modules
MPGDs	Triple GEMs	(~ 1 × 6 mm^2 Pad); ALTRO	8 rows of modules; ~17* 23 cm2 size;
	Micromegas (Resistive anode)	(~ 3 × 7 mm^2 Pad); AFTER	
	Pixel / InGrid	(~ 55 * 55 mm^2 pixel); TIMEPIX	100-120 chips per module; 25000-30000 chips per endcap

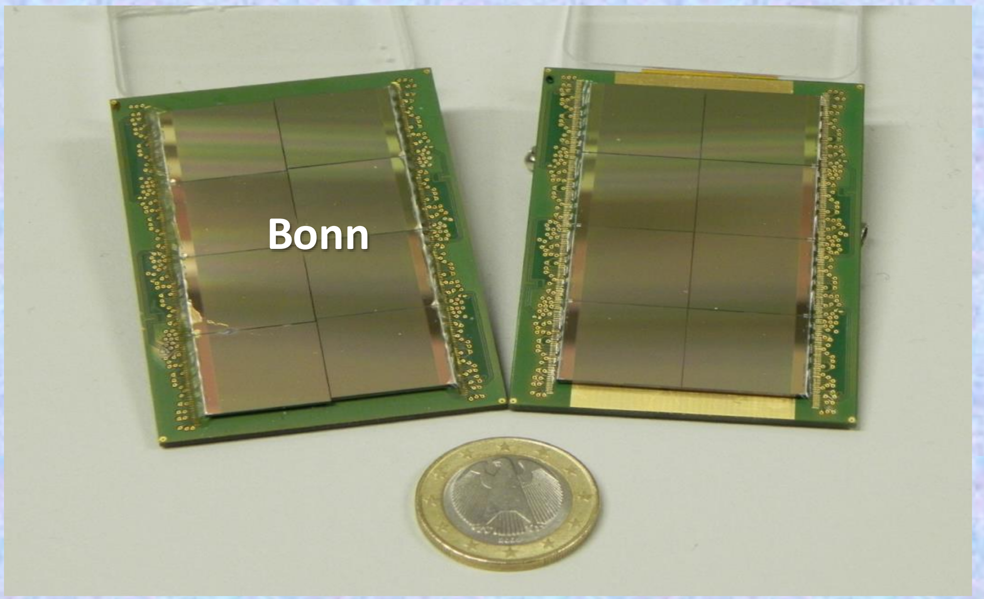
See ECFA LC2013 Yesterday's Talks (GEM / Micromegas Readout) →

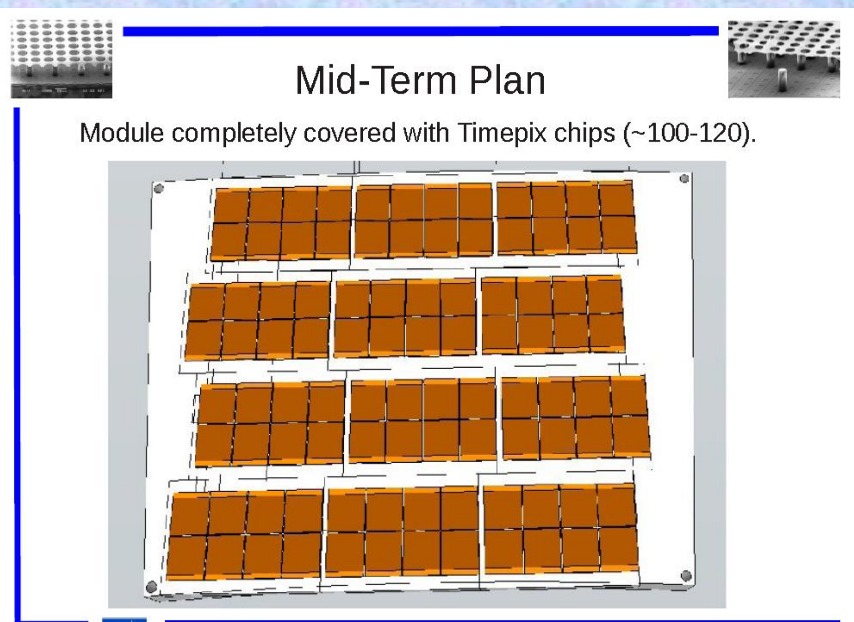
- ❖ Felix Müller (DESY), Beam Tests of the DESY GridGEM Module
- ❖ Klaus Zenker (DESY), Studies of a GEM based readout for the ILD TPC
- ❖ Junping Tian (KEK), Results from the 2012 beam test of the Asian GEM modules
- ❖ Alain Bellerive (Carleton University), Hit finding and pad response function for the LCTPC using resistive Micromegas

Pixel Readout of the ILC TPC

4 Octopuces : 2009 Saclay; 2013 NIKHEF ; 2013 Bonn (InGrid & Triple GEM)







Towards large-area assembly → see talk T. Krautscheid (Bonn University) , Production and Applications of Integrated Pixel Readouts for a LC

Simulation chain to compare momentum resolution, dE/dx and pattern recognition to pad-based readout & optimize geometry
→see talk Martin Killenberg (CERN), Occupancy studies for the CLIC TPC with pad and pixel readout

GEM and Micromegas Developments for DHCAL

SDHCAL, semi-digital HCAL:

3 readout thresholds to improve energy resolution w.r.t. pure digital

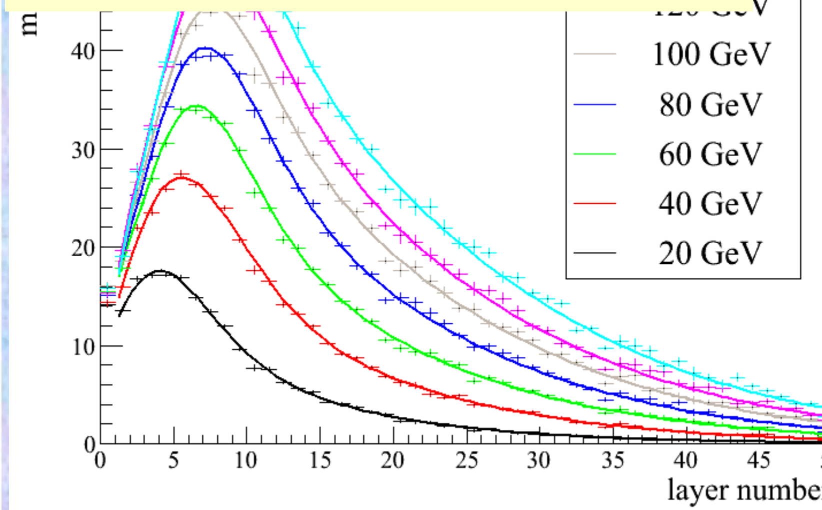
No saturation of signal in gas is important → Micromegas

Large area prototypes of 1x1 m^2

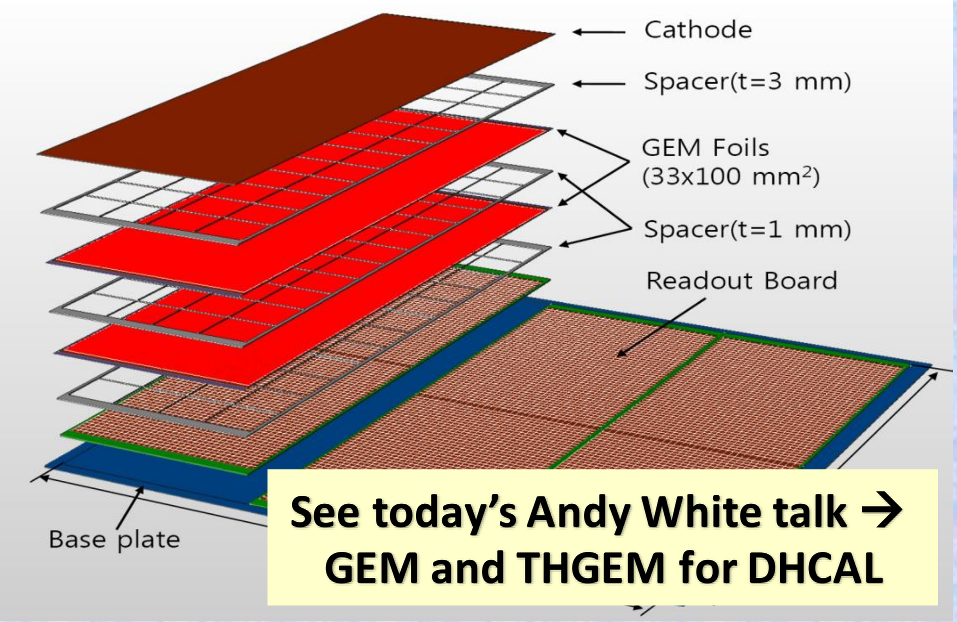
6 Bulk PCBs with embedded MICROROC ASICs

4 chambers (thickness < 1 cm) constructed and tested in beam (pad size 1cm^2)

See today's Iro Koletsou (LAPP) talk → Status of MM DHCAL



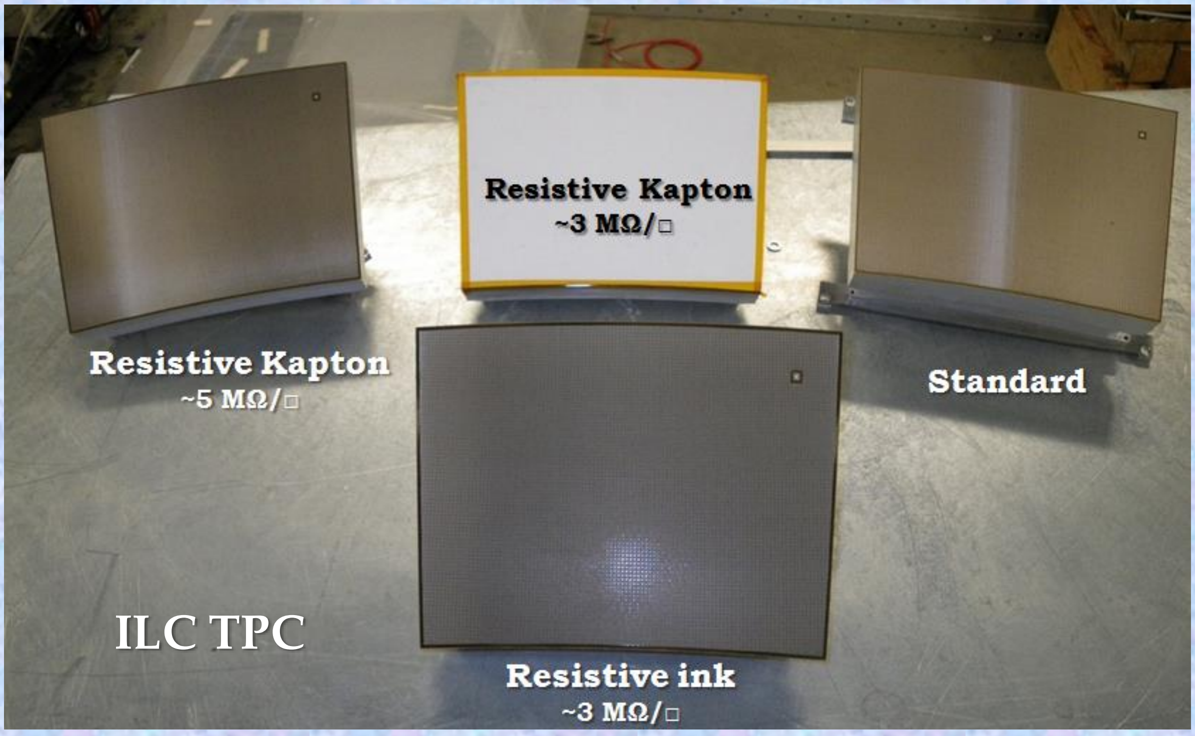
Towards Large Area 1 m x 1 m GEM Detector for DHCAL

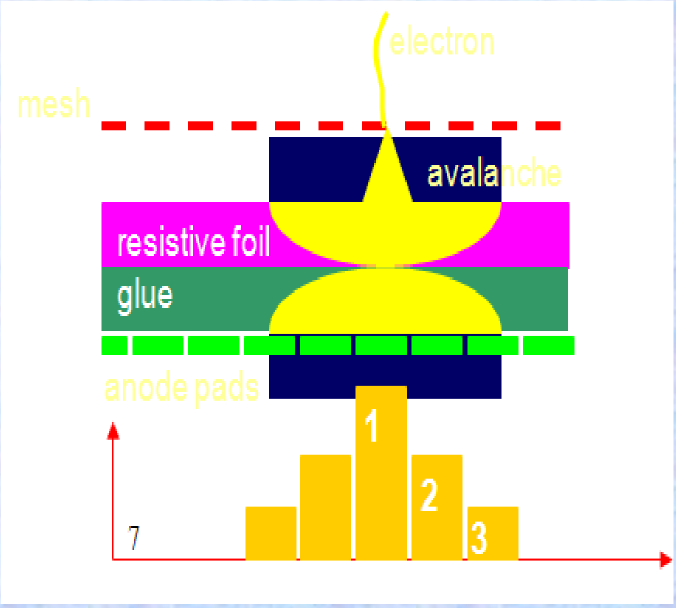


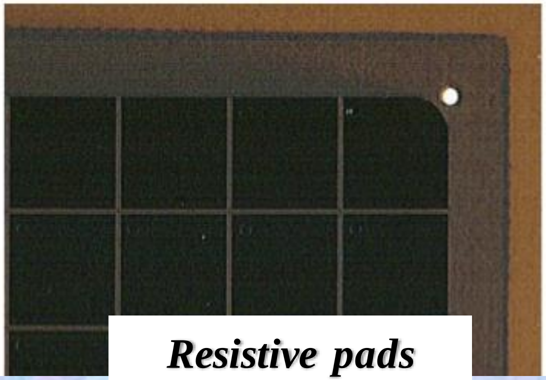
See today's Andy White talk → GEM and THGEM for DHCAL

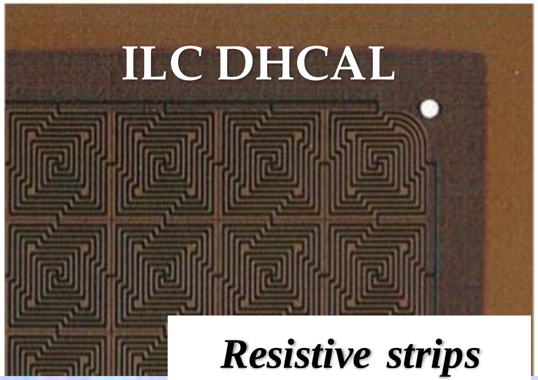
Micromegas Goes Resistive ...

Try different resistive configurations to improve momentum resolution by c harge sharing (ILC TPC) to protect against sparks (MM DHCAL)









RD51 WG4: MPGD Simulation Tools

- **Focus on providing techniques for calculating electron transport in small-scale structures**
- **The main difference with traditional gas-based detectors is that the electrode scale (~ 10 μm) is comparable to the collision mean free path**

❖ 1) Development and Maintenance of Garfield++:

Garfield++ is a collection of classes for the detailed simulation of small-scale detectors.

Garfield++ contains:

- electron and photon transport using cross sections provided by Magboltz
- ionisation processes in gases, provided by Heed and MIP
- ionisation and electron transport in semi-conductors
- field calculations from finite elements, boundary elements, analytic methods

- **Magboltz cross sections (Ar, Xe, He, Ne; GeH_4, SiH_4, $C_2H_2F_4$) are frequently updated in collaboration with LXCAT (http://www.lxcat.laplace.univ-tlse.fr)**

❖ 2) Simulation Improvements:

- Penning transfers; gain fluctuations; Neutron detection; Photon feedback; VUV fluorescence

❖ 3) Modeling for MPGD Applications:

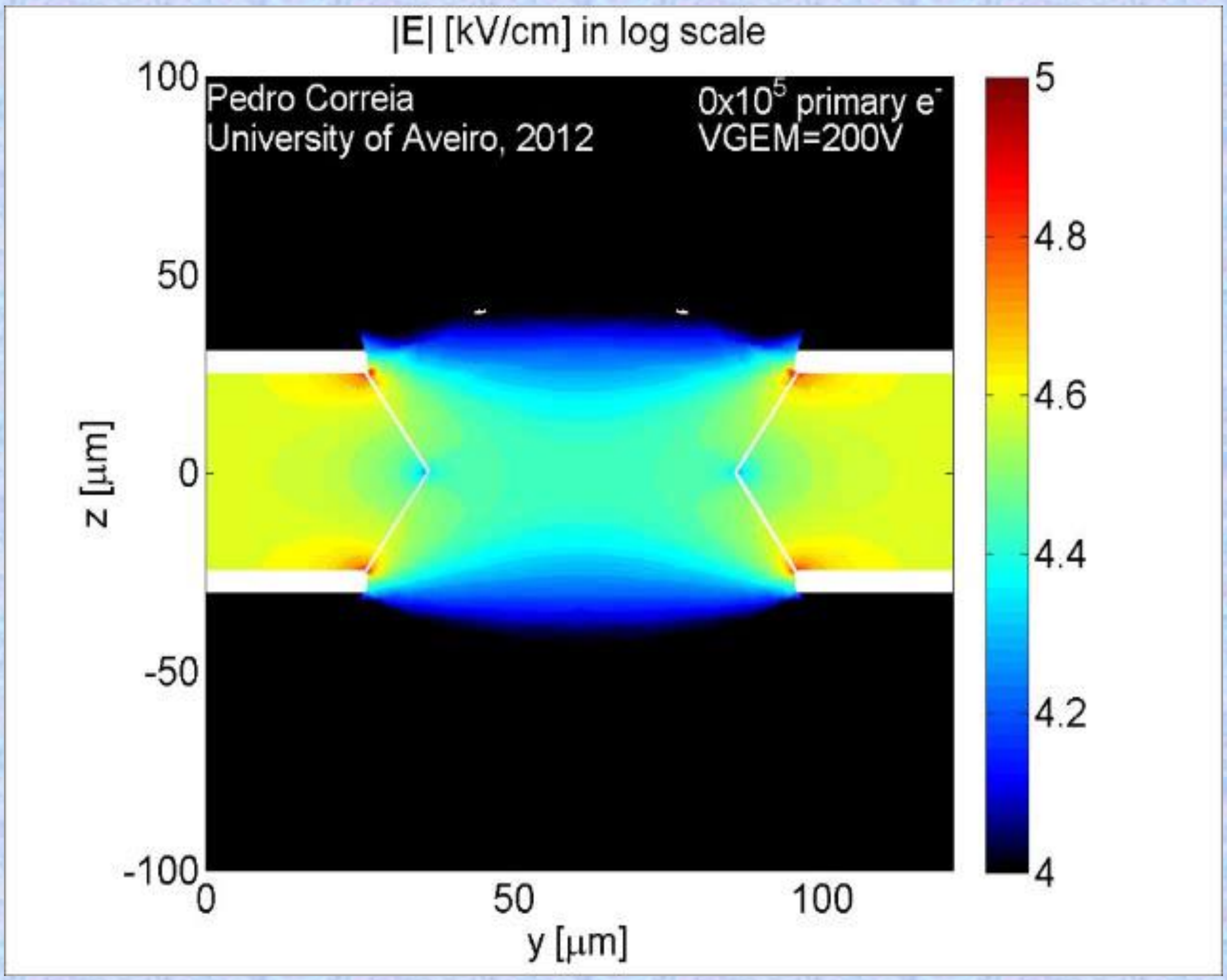
- Micromegas transparency
- GEM gain and charging up
- IBF for TPC Applications (e.g. ALICE GEM TPC)

WG4: GEM Charging-Up Effects Simulation

Electric Field Intensity during the charging-up process:

each iteration correspond to the number of primary electrons that already reached to the hole

- **ANSYS: field model**
- **Magboltz 9.0.1: relevant cross sections of electron-matter interactions**
- **Garfeld++: simulate electron avalanches**



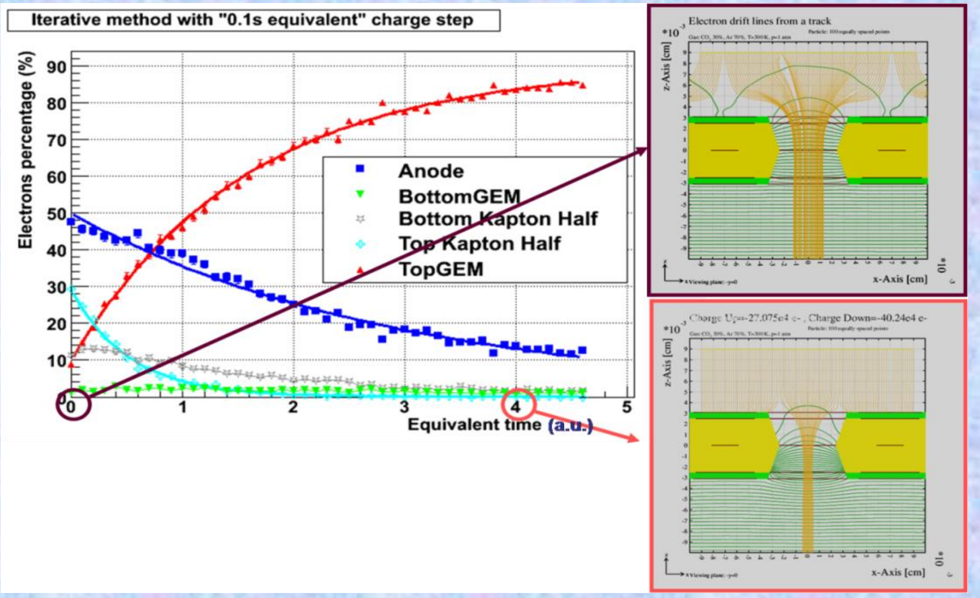
Pedro Correia
Rob Veenhof

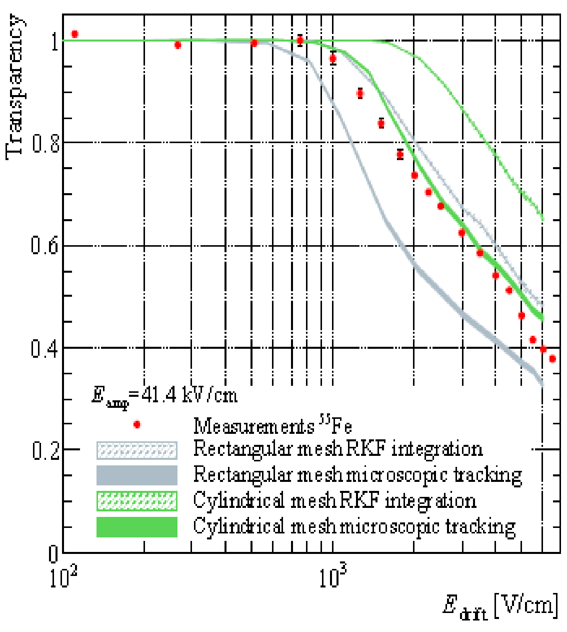
Charging effects are much smaller after (100 – 150) *10^5 avalanches → GEM gas gain stabilizes

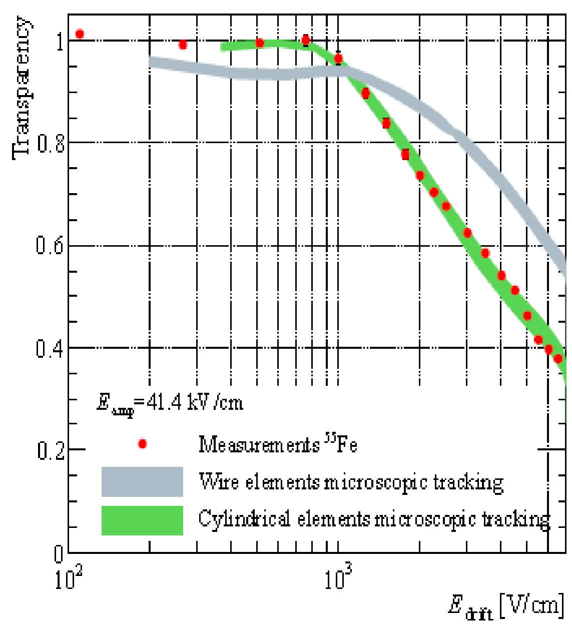
WG4: GEM Charging-Up and Micromegas Transparancy

GEM Charging- Up Effects:
f"manual" iterative
method (GEM simulation
with "0.1 s equivalent charge step

M. Alfonsi, NIMA671, 6 (2011)







Micromegas Electron Transparency:

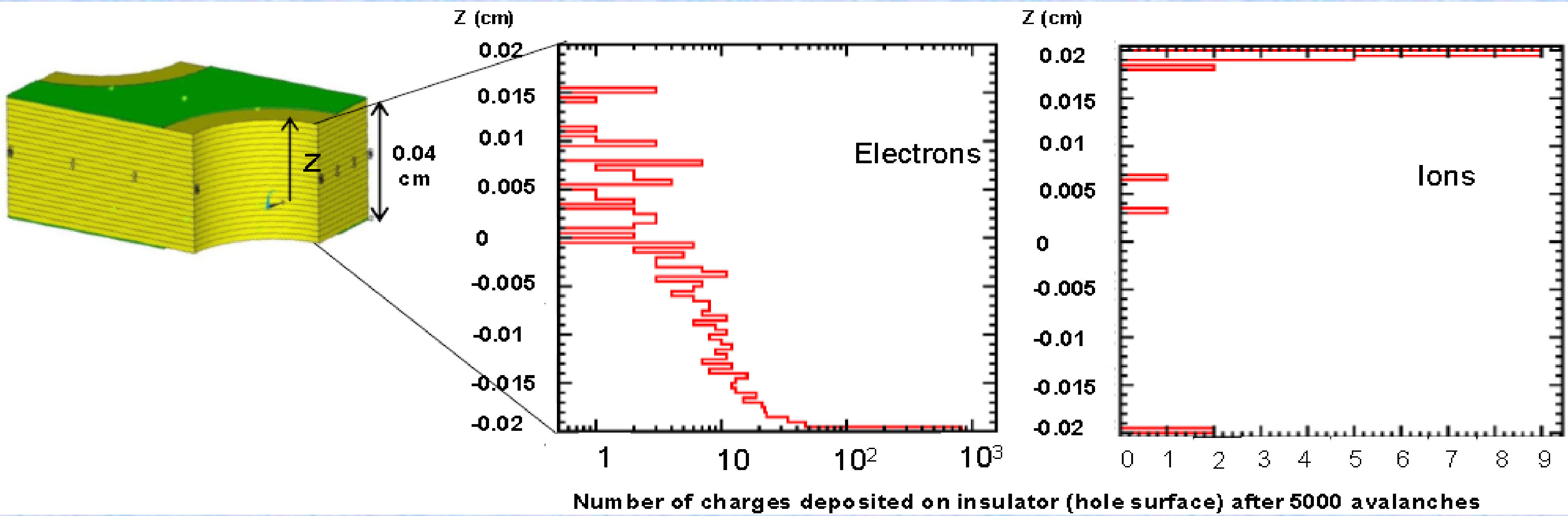
$P(\text{e-collection}) = S_{Drift} / S_{Total}$

$= S_{Amplification} \times \text{Field-Ratio} / S_{Total}$

~ (hole diameter)^2 ~ (wires pitch)^2

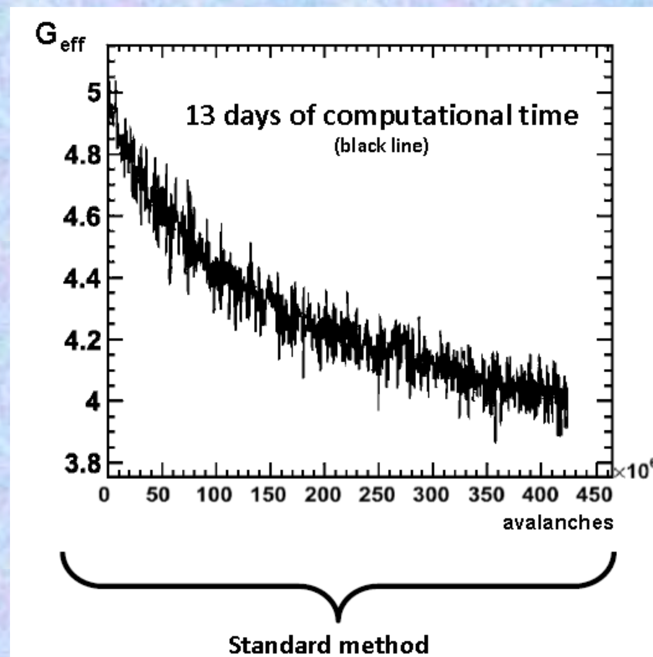
K. Nikolopoulos, JINST6 P06011 (2011)

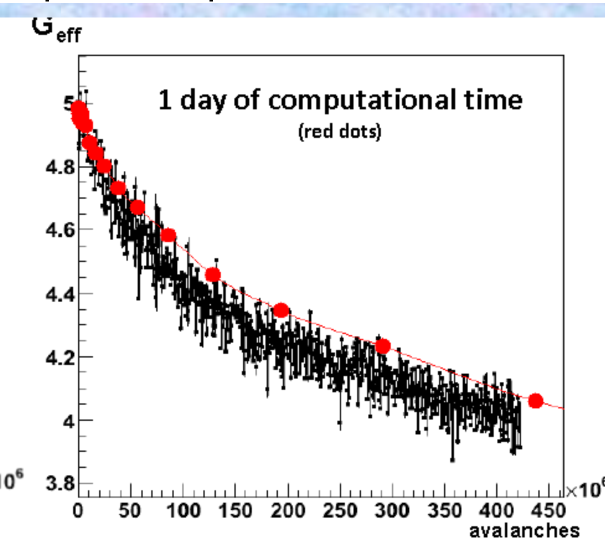
WG4: THGEM Charging-Up and Calculations



First Attempt to simulate THGEM Charging-Up Effects →

Dynamical method (significantly reduces time for simulation)





- Red points represent the dynamical step – only 20 points are needed to represent the same information obtained before ≈ 1 day of computational time
- Small deviation from previous results

R. Veenhof, RD51 Collaboration Meeting, january 2013

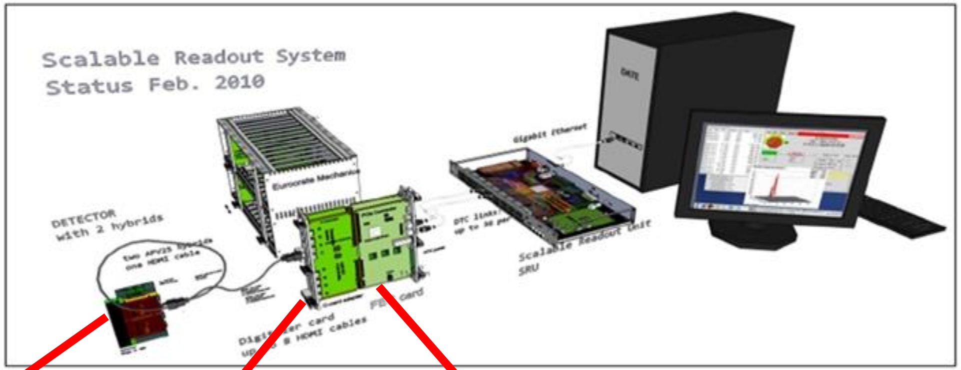
WG5: Development of Scalable Readout System (SRS) for MPGD

Development of a portable multi-channel readout system (2009-2012):

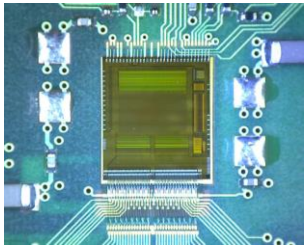
- ❖ **Scalable readout architecture:** a few hundreds channels up to very large LHC systems (> 100 k ch.)
- ❖ **Project specific part (ASIC) + common acquisition hardware and software**

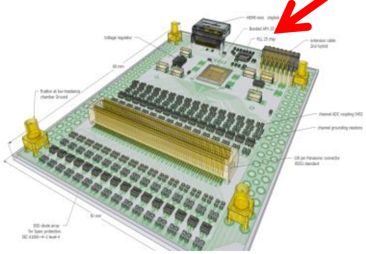
Physical Overview of SRS:

- Scalability from small to large system
- Common interface for replacing the chip frontend
- Integration of proven and commercial solutions for a minimum of development
- Default availability of a very robust and supported DAQ software package

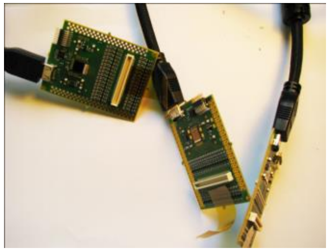


ASIC board with spark protections connected to detector → HDMI → Digitizer card (ADC) + Front-end concentrator card → DTC link → Scalable Readout Unit For multiplexing of event data → Gb Eth → PC with DAQ slow control soft. + analysis framework





Frontend hybrids: so far all based on APV25 chip, VFAT, Beetle, and Timepix being designed



ADC frontend adapter for APV and Beetle chips

ADC plugs into FEC to make a 6U readout unit for up to 2048 channels

FEC cards (common):
Virtex-5 FPGA, Gb-Ethernet, DDR buffer, NIM and LVDS pulse I/O, High speed Interface connectors to frontend adapter cards

WG5: SRS Users Status

Produced by PRISMA Company (Greece), sold via the CERN store

1. ALICE EMCal Calorimeter upgrade, ORNL, SRS readout backend via DTCC links and 24 SRU's , DATE Online system, being installed
2. ATLAS upgrade CERN, MAMMA project NSW , µMEGAS , APV frontend SRS Eurocrates-SRU, MMDAQ Online, installed
3. ATLAS upgrade Mainz, µMEGAS for MBTS, APV frontend- SRS Eurocrate, MMDAQ Online, waiting delivery
4. ATLAS Muon upgrade R&D, INFN Rome, APV frontend SRS Eurocrate, MMDAQ Online, delivered
5. ATLAS Saclay, µMEGAS R&D, APV frontend SRS Minicrate, MMDAQ Online, delivered
6. NA62 CERN straw tracker upgrade with µMEGAS, APV frontend with SRS Minicrate, MMDAQ Online, delivered
7. CMS upgrade CMS GEM collaboration CERN, Muon Endcaps, design of VFAT frontend digital readout SRS, ongoing with IFIN-HH
8. TOTEM upgrade GEMs Baris testlab, OPTO-Rx card design, Minicrate,Eurocrate, SRU, DATE Online, delivered
9. BNL GEM detectors, APV frontend-SRS Minicrate, RCDAQ Online, delivered
10. Stony Brook GEM detector R&D, APV frontend SRS Minicrate, RCDAQ Online, delivered
11. Bonn Phys. Inst. R&D for ILC, T24 DESY testbeam, Timepix Array Ingrid Module adapter for SRS , Eurocrate, Online unknown, ongoing
12. Florida Inst Tech GEMs, Muon Tomografy for Homeland security, 15k channel SRS prototype Eurocrate, DATE Online, delivered
13. Géosciences Azur-CNRS-UNSA, Muon Tomography w.µMEGAS for geology, APV frontend SRS Eurocrate, Date Online, delivered
14. GDD lab RD51, CERN, R&D for GEM and µMEGAS, APV frontend SRS Euro and Minicrates, DATE, Labview MMDAQ, delivered
15. HIP, HELSINKI, characterization MPGAD detactors, APV frontend SRS Eurocrate, DATE and Labview, delivered
16. INFN Napoli, ATLAS. Development of SRS Hardware and Firmware, Labview, delivered
17. Jefferson Lab, Virginia UVa upgrade GEM readout system, APV frontend SRS Eurocrate, DATE online, partially delivered
18. Yale University , GEM development ALICE, APV frontend SRS Eurocrate, DATE Online, delivered
19. NEXT Coll. small Xenon TPC with PM and Si PMs, SRS readout electronics co-development, SRS Eurocrate and SRU, DATE, delivered
20. UNAM, MEXICO, MX , R&D on THGEM, APV frontend SRS Minicrate, DATE Online, delivered
21. Radiation Laboratory, Nishina Center, RIKEN , APV frontend SRS Eurocrate, Online unknown, delivered
22. J-PARC /E16 experiment, GEM based tracking, APV frontend SRS Minicrate, Online Unknown, partially delivered
23. Jefferson Lab SHM spectrometer triple GEM, APV frontend SRS Eurocrate, DATE Online, waiting
24. Harward Univ. Physics, APV frontend SRS Minicrate, Online unknown, waiting
25. Tokyo Univ. ATLAS, APV frontend SRS Eurocrate, Online unknown, waiting
26. WIS and Aveiro Univ. GEM validation, APV Frontend SRS Eurocrate, MMDAQ and Labview, being delivered
27. East Carolina University, Health Physics, APV frontend, SRS Eurocrate, Labview, waiting
28. Munich LMU / ATLAS µMEGAS, APV frontend SRS Eurocrate –SRU, MMDAQ Online, partially delivered
29. NCSR Democritos ATHENS, APV frontend SRS Minicrate, Online unknown, waiting
30. IFIN-HH-Bucharest new Detector lab, APV and VFAT frontend, SRS Eurocrate and SRU, Labview, delivered
31. ATLAS NSW CERN, SRS-ATCA pilot system, MMDAQ Online, waiting
32. ALICE FOCAL ORNL, SRS-ATCA pilot system, DATE Online, waiting
33. NEXT Collaboration, SRS-ATCA pilot system, DATE Online, waiting
34. Lunds Univ, ILC TPC, SRU for 24 channel DTCC link readout, Online unknown, delivered

WG5: Potential New SRS Users

1. LAPP, Annecy, SRS hybrid with MicroROC chip for ATLAS , no news
2. Pacific Northwest National Laboratory, Radiation detection and Nucl. Sci, interest in APV SRS system, no CERN team account
3. Radcore LTD Republic of Korea, GEM production , small SRS system , no team account
4. Newflex GEM production, South Korea , small SRS system , enquiry status
5. GIF++ team CERN, interested in SRS as GIF++ base installation with DATE Online system , ongoing discussions, waiting
6. Budker INP, Novosibirsk, Deuteron Exp. @ VEPP-3 , APV readout SRS , APV order impossible, radhard export restriction
7. Tsinghua Univ. China , R&D on GEM Imaging detectors, APV readout SRS , APV order impossible, radhard export restriction
8. SAHA Inst Nucl Phys,KOLKATA, IN , Laboratory for characterization of MPGDs , APV order impossible, radhard export restriction
9. USTC Shanghai, CN , characterization of GEM and MicroMega with SRS , APV order impossible, radhard export restriction
10. Univ . Texas, DOE proposal with 18 GEMs , no news
11. National Univ. of Colombia, Dosimetry for mediical appl, no team account, no news
12. BNL Phenix upgrade, small SRS systems already delivered , no news
13. Helsinki University, Totem , no news
14. Freiburg University, verbal enquiry for SRS system, no news
15. Univ Calabria It, email enquiry for SRS, no news
16. Uni. Kobe, JP J-PARC /E16 upgrade , large SRS system, prelim offer sent
17. ALICE ITS, SRS 16 ch. ADC card for test of ITS chips , enquiry
18. NEOHM Italy, SRS system for test of hybrid production for CERN store, sending offer
19. Geoazur-CNRS-UNSA, Valbonne, FR, upgrade of existing SRS uMega readout systrem, APV readout Eurocrates ,waiting for news

❖ A main feature of SRS, apart from its scalability, portability and affordable cost (< 2 EUR/ channel), is possible choice of the frontend ASIC in the future (APV, VFAT, Beetle, VMMx, Timepix).

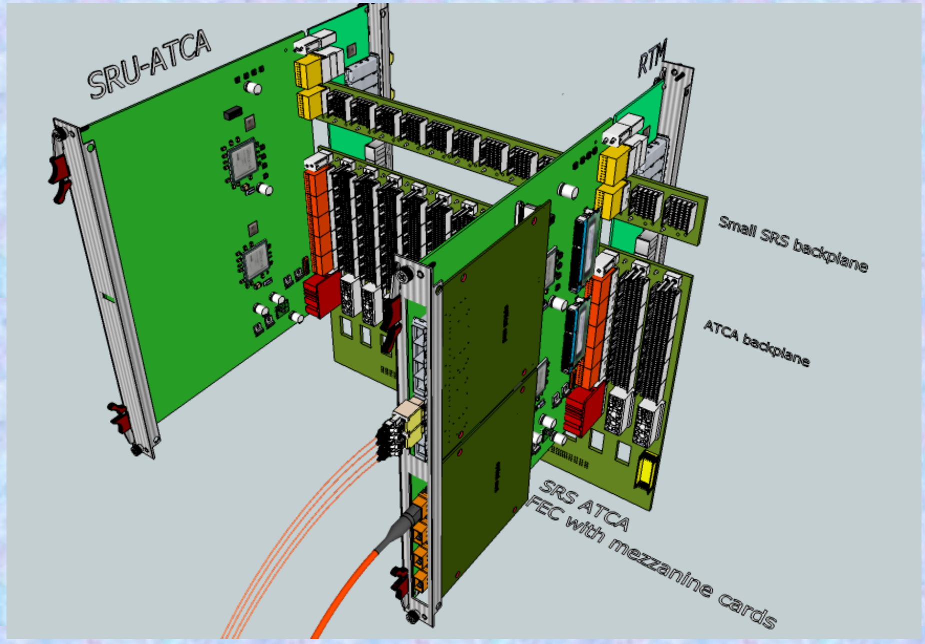
❖ System was used for R&D for upgrades in ATLAS, CMS, ALICE ECAL and for … ☺☺☺ … SiPM readout

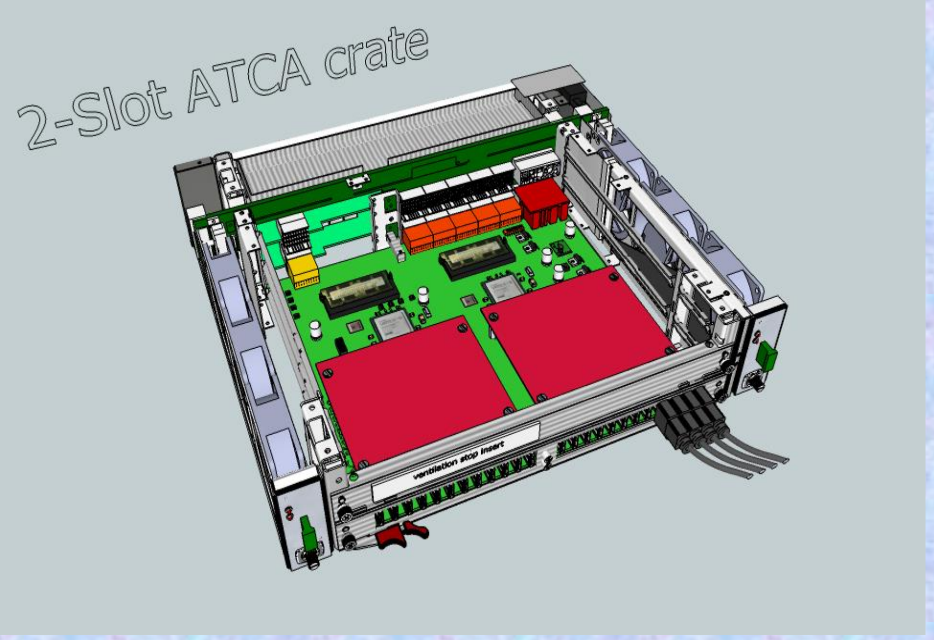
WG5: Large SRS Systems in ATCA Technology

ELMA and EicSys GmbH, Germany started to rework the "SRS classic" system into the industry Advanced xTCA standard (ATCA), targeting larger experiments and commercial applications.

SRS ATCA*- fully commercial SRS in certified ATCA Crates

1.) higher channel integration => reduce cost/channel for large systems
2.) certified crate standard 3.) replace DTCC cables by ATCA backplane
4.) start with 2-slot ATCA crate that can be read out via SRU



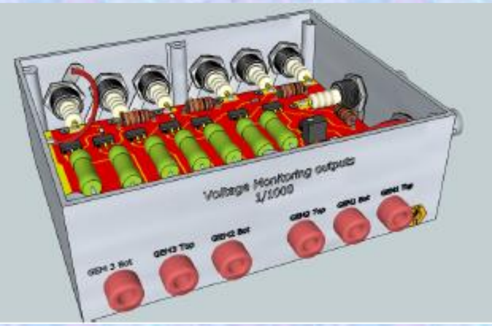


Delivery of the first ATCA SRS expected in June – July 2013

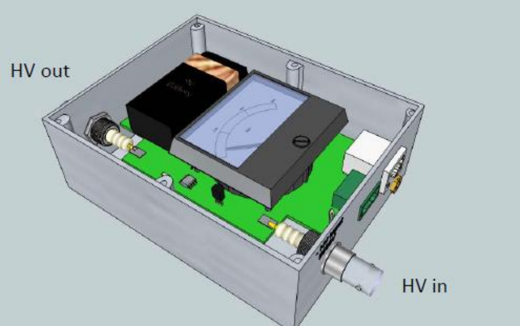
WG5: Towards a complete SRS-Lab equipment for MPGDs

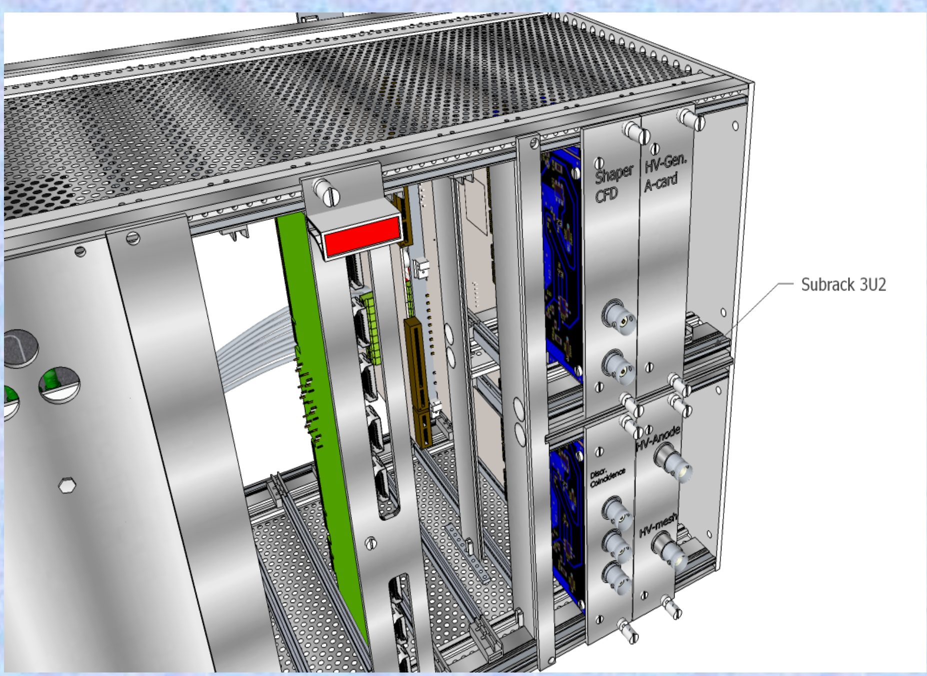
- AVD box : active Voltage Divider with monitoring for GEMs (under test)
- Remote I2C readout of AVD and CM via SRS (in progress)
- CM box: Current monitoring range 10 pA -100 uA (design status)
- QSA frontend: quad signal amplifier 2 GHz, factor 20, for MPGD's (tb revised)
- TPB trigger pickup box: generates triggers from Meshes (working in several places)
- I-GEM: Anode current summing hybrid for GEMs (planned)
- Shaper-Discriminator: SRS card 50 OHM triggers from TPB (planned)
- HGM: SRS card , programmable High Voltage for mesh grounded MM (design status)

Active Voltage Divider for GEM's

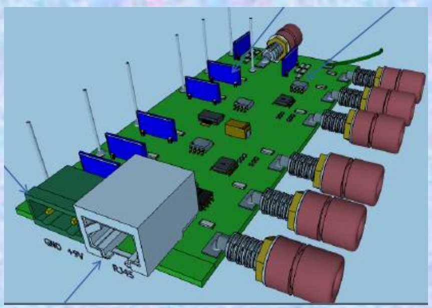


High Voltage pAmmeter

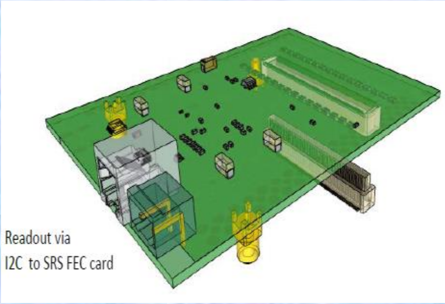




High Voltage Monitoring

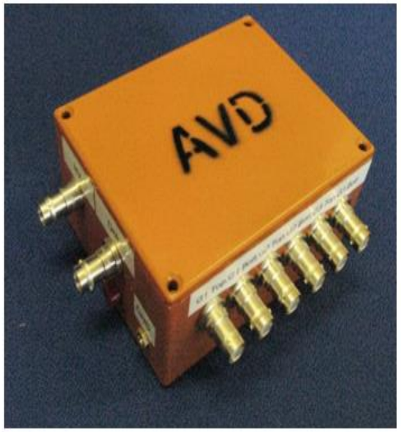


Readout pAmmeter

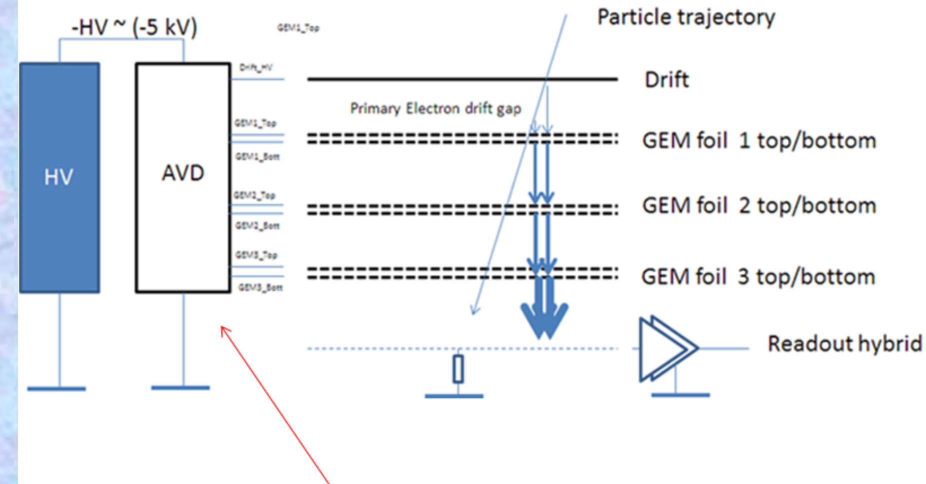


Hans Muller (CERN) et al.,

WG5: Active High Voltage Divider for GEMs



- Stabilize Voltages of GEM foils in high-rate applications
- Reduce noise by low impedance HV outputs
- Protect Voltages at GEM foils against shorts in other GEM foils
- Precision output of kilo-Volt levels by 1/2000 factor to DVM/oscilloscope
- Online readout via cable to SRS
- Include measurements of ambient temperature and humidity
- Planned 2nd step: add CM box for Picoampere readout in all lines



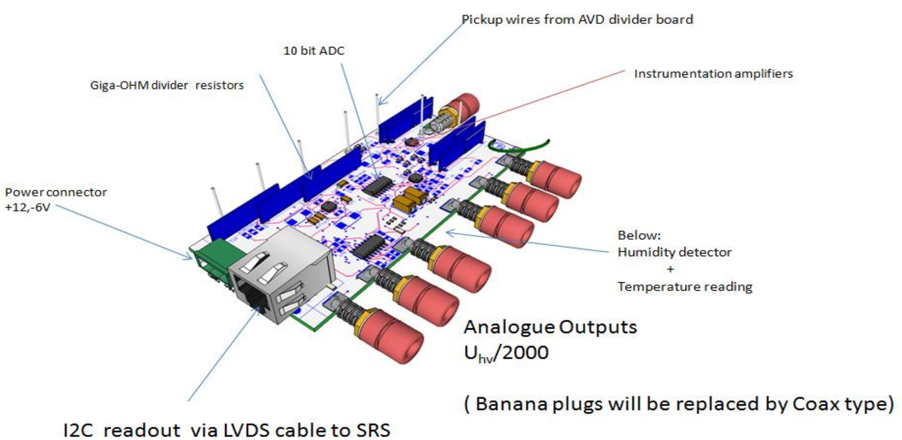
Principle inside AVD:

a.) use high-ohmic resistor divider to bias HV Transistors to obtain constant, low impedance output voltages

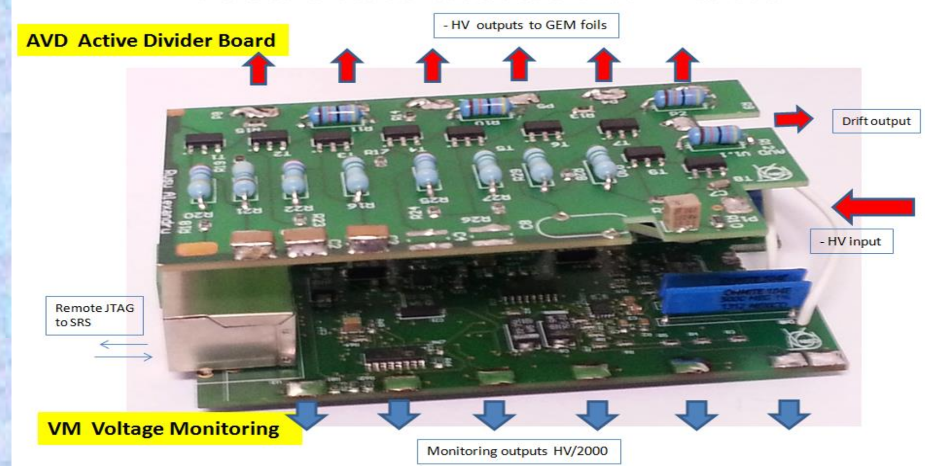
b.) use GigaOHM dividers and instrumentation amplifiers for HV monitoring (static and dynamic down 10 ns)

c.) static readout via remote I2C cable to SRS

HV monitoring board (VM)

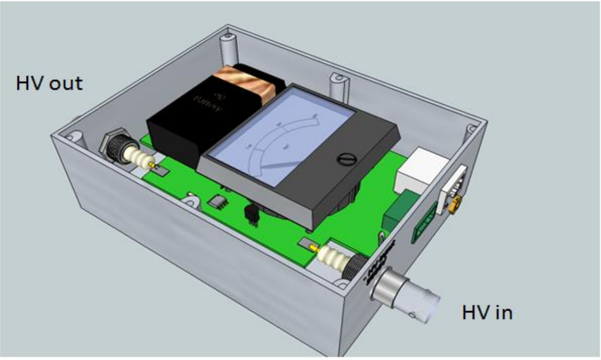


Electronics inside AVD box



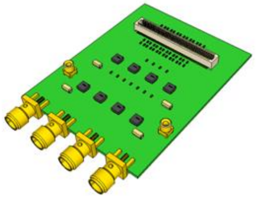
WG5: PicoAmp, Auqd Signal Amp and Trigger Pickup Boxes for MM

PicoAmp box (planned)

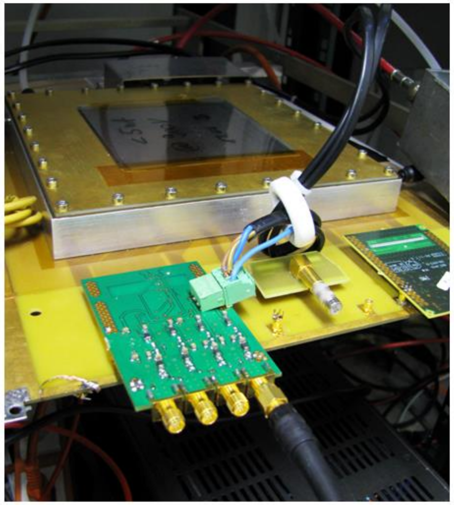


SRS readout cable connector

QSA Quad Signal Amplifier for MPGD's



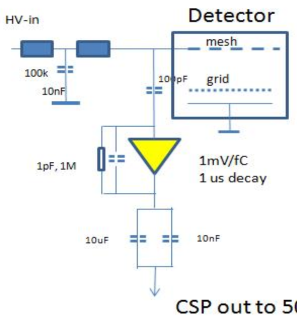
2.4 GHz preamplifiers
of 4 neighboring detector channels.
Gain Vout/Vin = 20
⇒ Monitor detector signal dynamics below the millivolevel at full BW



QSA board to be revised to suppress ringing

Trigger pickup box

Designed to pick up induced charge on grid or mesh
Converts charge to voltage via our proprietary CSP amplifier
50 OHM fast signal for external shaper /discriminator



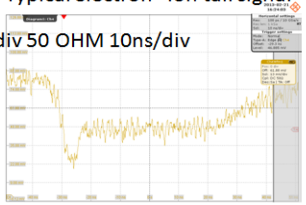
CSP out to 50 OHM

CSP
1mV/fC
1 us discharge

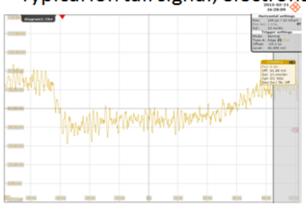
Types of signals on MM strip

Typical electron –ion tail signal

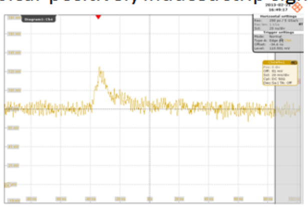
13mV/div 50 OHM 10ns/div



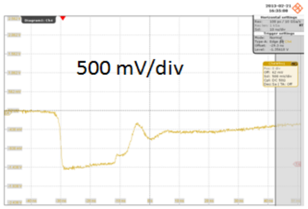
Typical ion tail signal, electrons suppresed



Typical positively induced strip signal



Typical discharge (large vertical scale)



WG6: CERN Workshop Upgrade for the MPGDs

- Today, CERN-MPGD workshop is the UNIQUE MPGD production facility (generic R&D, detector components production, Q&A quality control)

- Future Upgrade of the workshop approved by CERN management (Nov. 2009):

Installation of NEW infrastructure to fabricate 2x1m Bulk MM and 2x0.5 m GEMs COMPLETED

2009 RD51 Survey:

Detector technology	Currently produced	Future requirements
	cm * cm	cm * cm
GEM	40 * 40	50 * 50
GEM, single mask	70 * 40	200 * 50
THGEM	70 * 50	200 * 100
RTHGEM, serial graphics	20 * 10	100 * 50
Micromegas, bulk	150 * 50	200 * 100
Micromegas, microbulk	10 * 10	30 * 30
MHSP (Micro-Hole and Strip Plate)	3 * 3	10 * 10

2012 Status/Machine Delivery:

GEM	market survey	call for tender	order	received	ready
– 1 continuous polyimide etcher	x	x	x	x	06/2011
– 1 Cu electroetch line	x	x	x	x	06/2011
Micromegas					
– 1 large laminator	x	x	x	x	06/2011
– 1 large Cu etcher	x	x	x	x	09/2012
– 1 large UV exposure unit	x	x	x	x	06/2011
– 1 large resist developer	x	x	x	x	09/2012
– 1 large resist stripper	x	x	x	x	09/2012
– 1 large oven	x	x	x	x	06/2011
– 1 large dryer	x	x	x	x	06/2011

ATLAS Muon System Upgrade (Micromegas) and CMS Muon System Upgrade (GEM) has been approved as upgrade projects for the LS2

WG6: MPGD Technology Industrialization

Technology Industrialization → transfer "know-how" from CERN workshop to Industrial partners for MASS PRODUCTION

THGEM Technology: ELTOS S.p.A (Italy), PRINT ELECTRONICS (Israel)

POTENTIAL PARTNERS:

GEM Technology:
- Tech-ETCH (USA, Boston)
- Scienergy (Japan, Tokyo)
- Techtra (Poland)

Micromegas Technology
- TRIANGLE LABS (USA, Nevada)
- ELTOS S.p.A. (Italy)
- SOMACIS (Italy, Castelfidarco)
- ELVIA (France, CHOLET)

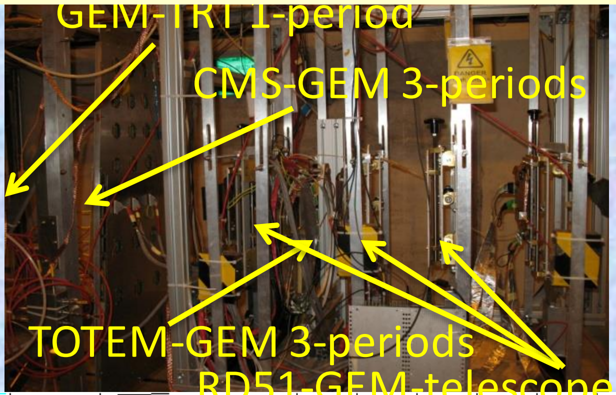
GEM Licenses Signed by:

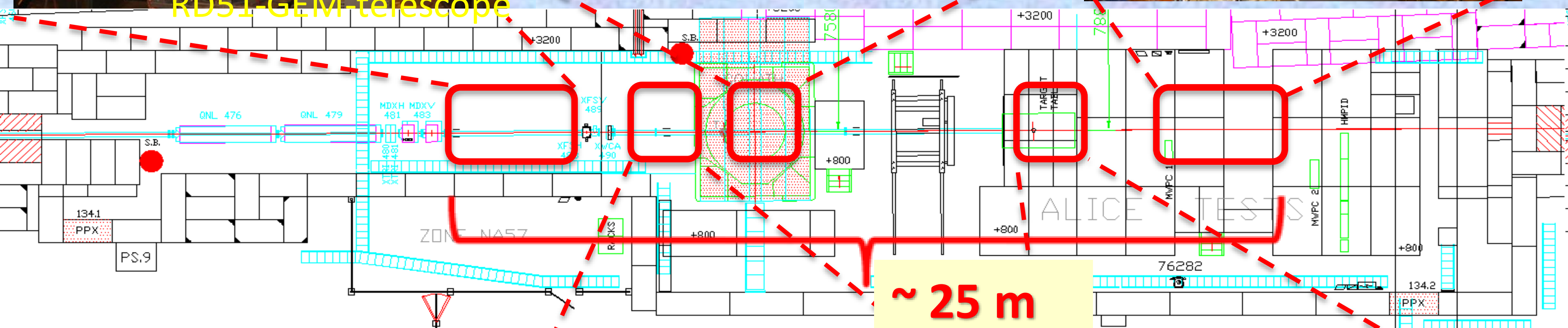
- ❖ TECH-Etch, signed 06/03/2013
- ❖ China Institute of Atomic Energy, signed 10/01/2012
- ❖ Sci Energy, signed 06/04/2009
- ❖ Techtra, signed 09/02/2009
- ❖ CDT, signed 25/08/2008
- ❖ PGE, signed 09/07/2007

- ❖ **2012-2013:** Industrial test runs for GEM and MM in companies (Techtra, ELTOS, ELVIA)
- ❖ **2013:** Two large area MMs (1*0.5 m^2) are ordered in ELVIA for GEOAZUR Project (Tomography Densitometric Meas.); 4 more det. to be produced at CERN

WG7: Common Test Beam Facility at H4 SPS

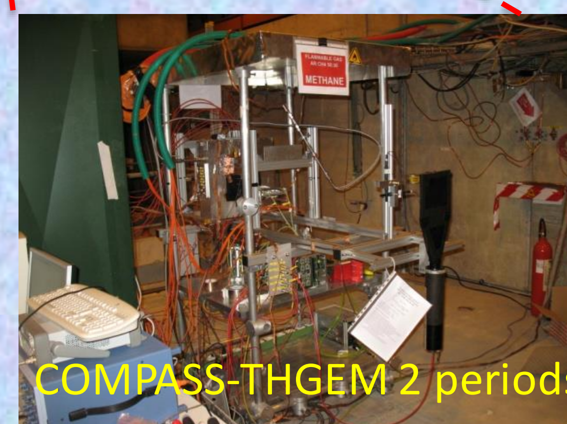
Common RD51 infrastructure: GEM and MMs beam telescopes, HV, gas & power lines …





- **2008-2013: > 15 RD51 groups participated;**

- **3-beam telescopes exist: 1 Bulk MM, 1 resistive MM and 1 triple-GEM with SRS readout**



Future RD51 Activities and Outlook

2008- 2013 RD51 Collaboration Approved for the 5-years term
2013 – Official Request to the LHCC to prolong RD51 for the next 5-years

- ❖ Continuation of the R&D support for the experiments in many domains (…), and LHC upgrades, in particular (WG1);
- ❖ Generic R&D (new structures/ideas, det. physics) – RD51 Common Projects (WG2)
  Development of new structure and consolidation of the existing structures
- ❖ Applications – organization of series of specialized workshops disseminating MPGD applications beyond fundamental physics –
  RD51 research + industry + potential users (WG3)
- ❖ Development and Maintenance of Software & Simulation Tools;
  basic studies & software support for the RD51 community (WG4)
- ❖ Development and Maintenance of the SRS Electronics (WG5)
  An extended support for the SRS including new developments and implementation of additional features …
- ❖ MPGD Industrialization and QA Control – GEM, Micromegas, THGEM (WG6);
  Completion of the industrialization of main technologies (GEM, MM, THGEM)
- ❖ Maintenance and extension of the RD51 lab and Test-Beam Infrastructure (WG7)
- ❖ MPGD Education and Training: organization of schools for students and newcomers & academic Training (NEW WG)