Efforts for industrialization of GEMs and Micromegas at CERN

Outline:

1) WG6 in the RD51 context
2) CERN common infrastructure improvements
3) Future requirements in LHC experiments
   (CMS, Atlas, Alice, LHCb)
4) Technology transfer: potential partners
   (Newflex, Eltos, Cirea, Techtra, TechEtch)
5) CERN workshop resources on MPGDs
6) Micromegas resistive training at CERN
7) Conclusions

WG6 in the RD51 context

Efforts for industrialization are coordinated within RD51

- **~ 80 institutes**
- **~ 450 people involved**
- **Representation (Europe, North America, Asia, South America, Africa)**

	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 (technology transfer)	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

WG6 offers an open framework for technology transfer and industrialization activities

Coordinators: R. de Oliveira (CERN), I. Giomataris (CEA Saclay), F. Formenti (CERN),

CERN TE-MPE-EM fine pitch photolithography workshop is part of WG6 (R. de Oliveira)

- Provides common infrastructure for R&D and development of MPGDs
- Train own personnel and maintain competences in the domain
- Collaborate w/ industrial partners to define compatible processes and QC procedures

CERN common infrastructure improvements

- Some collaborations indicate tendency towards increasing detector sizes
- Motivations: improved active area, better integration modularity, lower costs @ same yield, …
- The table below shows some indicative numbers

Detector Technology	Past limitations (cm x cm)	Being moving towards (cm x cm)
GEM, double mask	40 x 40	50 x 50
GEM, single mask	70 x 40	200 x 60*
THGEM	70 x 50	200 x 100
RTHGEM, serial graphics	20 x 10	100 x 50
RTHGEM, Kapton	50 x 50	200 x 100
Micromegas, bulk	150 x 50	200 x 100
Micromegas, microbulk	10 x 10	30 x 30

Indicative table

(*) Limited by raw material

Consequence: new infrastructures are needed to face large size detector fabrication

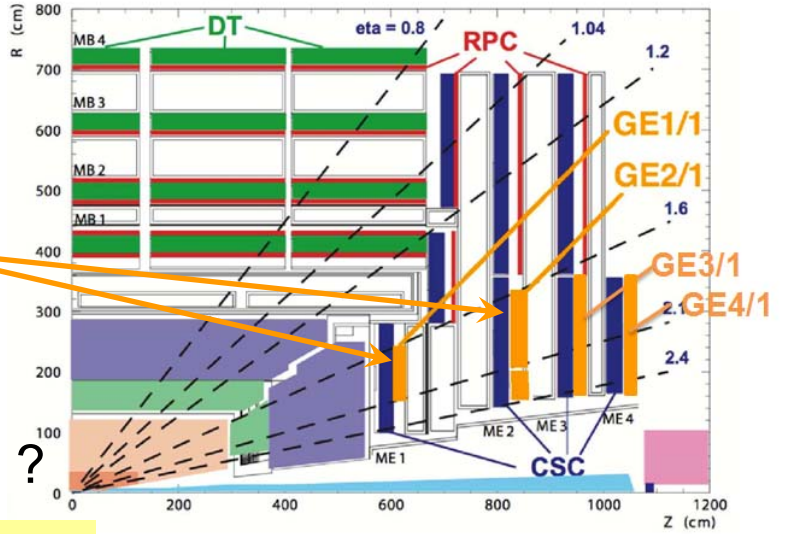
CERN has upgraded nine process machines (last three planned installation in May) and presently is performing large size prototype development

Not yet all fixed, but wise keeping an eye on these possible future needs

Future requirements: CMS muon upgrade

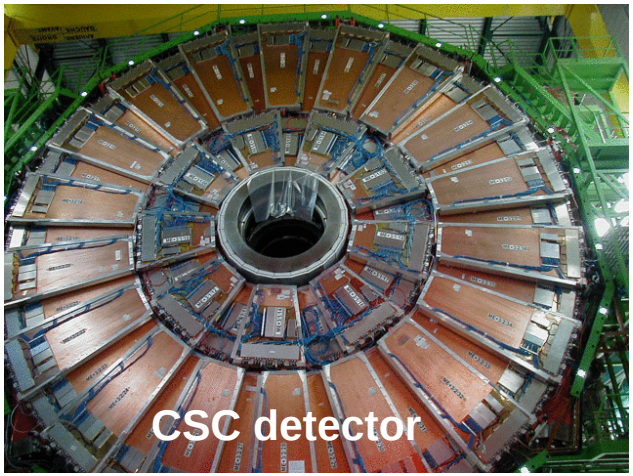
- GEM proposed as technology to withstand the high rate requirement for eta>1.6
- Priority for integration stations 1 and 2
- Installation (full/partial) during LS2 (2018)
- TP has been submitted on February 10th
- TDR by end 2012 for approval spring 2013 ?

Time



Scenario for two full inner stations - Dates reflect preliminary plan

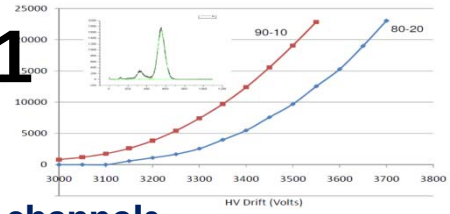
Station	Nbr of modules	Module area (containing rectangle)	Total Nbr of modules (w/o spares)	Total GEM foil area (3ple GEMs)	Manufacturing plan
GE1/1	18x2x2=72	~0.43m^2 (440x990)	72	0.43x72x3 =93m^2	Yrs 2014+2015
GE2/1	36x2=72 (long) 36x2=72 (short)	~2.4m^2 (1251x1911) ~1.6m^2 (1251x1281)	144	(2.4+1.6)x72x3 =864m^2	Yrs 2015+1016



About 1000m^2 of GEM foils in total

216 triple GEM detectors

CMS GEM Collaboration: prototypes 2010-11

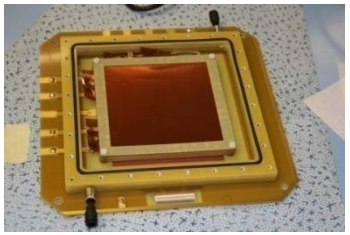


Small prototypes

CMS_timing_GEM: Standard double mask 10x10cm² 1D readout (3/2/2/2); 256 channels

SingleMaskGEM: Single Mask 10x10cm² 2D readout (3/2/2/2) 512 channels

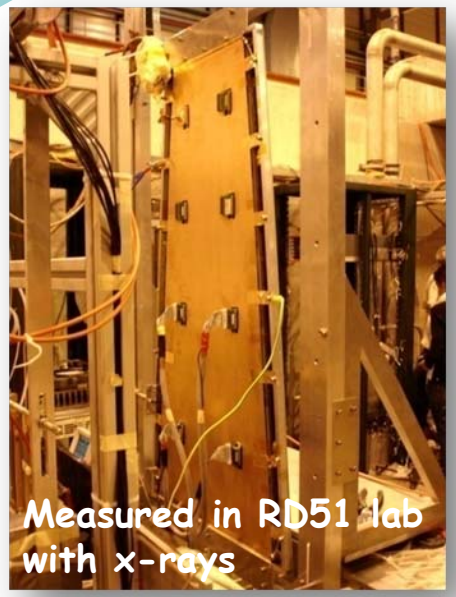
Honeycomb: Standard double mask 10x10cm² 1D readout (3/2/2/2); 256 channels



CMS_Proto_III Single Mask 10x10cm² [N2] (3/1/2/1); 256 channels

Korean_I Double Mask 7x7cm² (3/2/2/2); 256 channels

(Courtesy of Archana Sharma)



Full-size prototypes 2010/11

CMS_Proto_I: Single mask FULL_SIZE 1D readout (3/2/2/2); 1024 channels

CMS_Proto_II: Single mask FULL_SIZE 1D readout (3/1/2/1); 3072 channels

CMS_Proto_IV Single Mask 30x30cm² [NS2] (3/1/2/1); 256 channels

4 Production Prototypes (NS2) on the way 2012

CMS_Proto_V: Single Mask FULL_SIZE 1D [NS2] (3/1/2/1) ~3840 channels

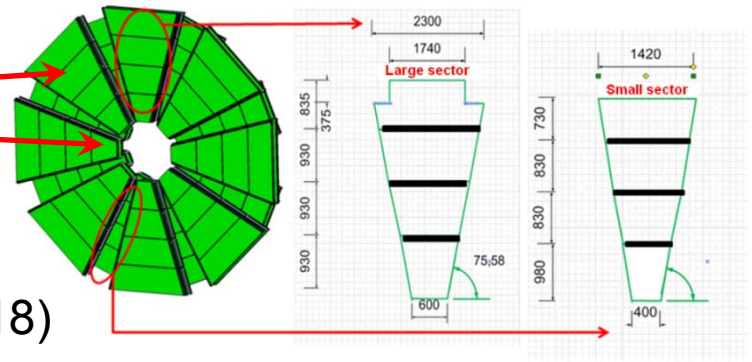
It's a long way to get the final device all right

R&D is one of the main responsibilities of the MPE-EM workshop

Industry has to follow standard learning steps before achieving final expertise

Future requirements: Atlas nSW upgrade project

- Micromegas proposed as competitive technology w.r.t. MDT+TGC and CSC

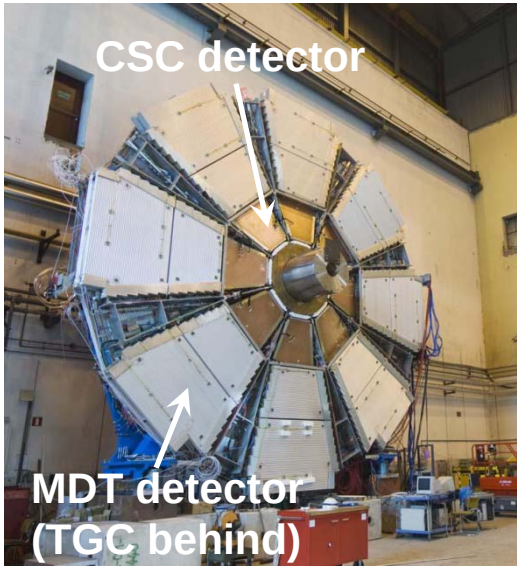


- Substitute small wheel muon stations
- Commissioning/installation during LS2 (2017/2018)
- Pre production 1st complete sector 0 (32 MM layers in 2014)
- MoU in 2012 ? and TDR during 2013 ?

Time

Scenario for full nSW - Dates reflect preliminary plan

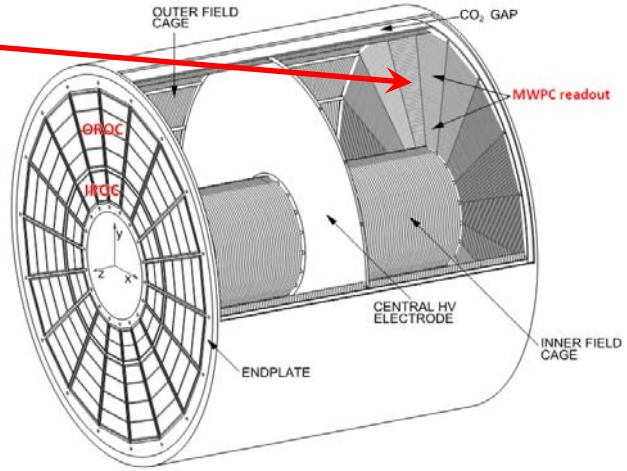
Sector	Nbr sectors Nbr chambers/sector MM layers/chambers	MM layer area (containing rectangle)	Total Nbr MM layers (w/o spares)	Total MM PCB area	Manufacturing plan
Small	8x2=16 4 4x2=8	From ~0.68m^2 (696x980) To ~1m^2 (1420x730)	512	0.88x512 =450m^2	Yrs 2015+2016
Large	8x2=16 4 4x2=8	From ~0.96m^2 (1036X930) To ~1.9m^2 (2300x835)	512	1.5x512 =768m^2	Yrs 2015+2016



About 1200m^2 of resistive bulk
1024 MM layers

Future requirements: Alice TPC upgrade

- GEM proposed as technology for high rate capability upgrade w.r.t. MWPC readout

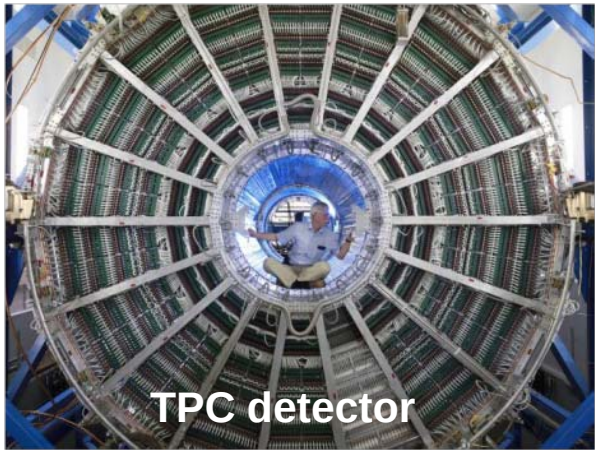


Time

- Installation during LS2 (2018)
- Commissioning 2017
- MoU in 2012 and TDR during 2013 ?
- 2012 production 1 IROC prototype for tests
- 2012 build collaboration and validate concepts

Dates reflect preliminary plan

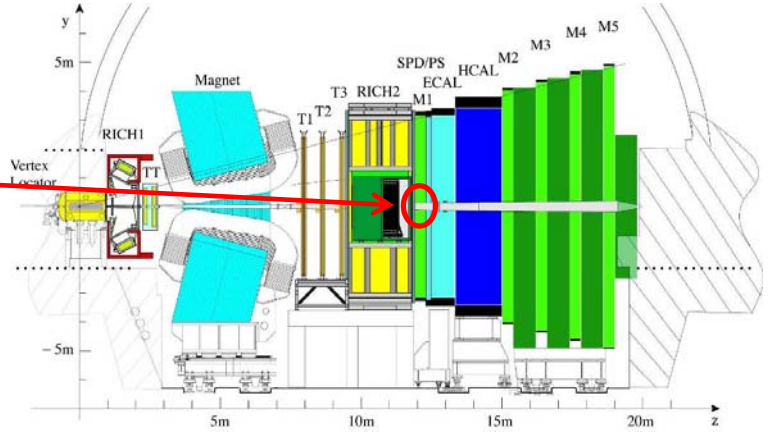
Module	Nbr of modules	Module area (containing rectangle)	Total Nbr of modules (w/o spares)	Total GEM foil area (3ple GEMs)	Manufacturing plan
IROC	18x2=36	~0.23m^2 (460x500)	36	0.23x36x3 =25m^2	Yr 2016
OROC	18x2=36	~1m^2 (880x1120)	36	1x36x3 =108m^2	Yr 2016

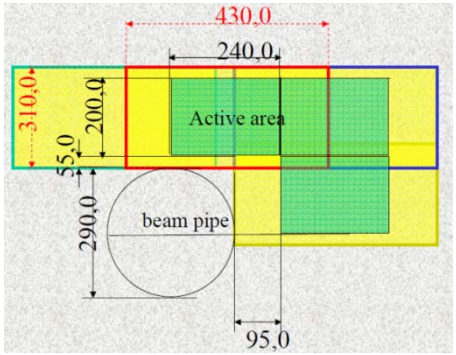


About 130m^2 of GEM foils in total
72 triple GEM detectors

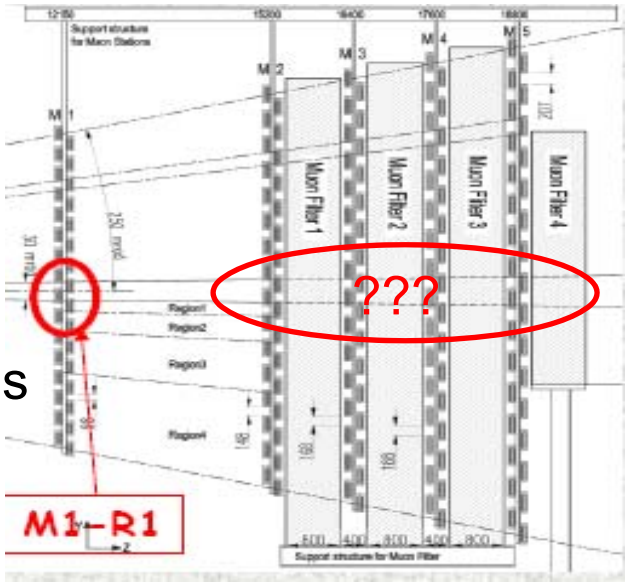
Future requirements: LHCb ?

- TODAY:
- GEMs are installed in M1 muon detector at the innermost region R1
- 12 double stations of triple GEMs
- Size 310x430 (active 200x240)
- Total GEM foil area ≈ 10m^2





- IN FUTURE:
- Till now not yet any known plans to instrument more inner regions of muon detectors with GEMs
- But if …
- Estimated additional total surface ≈ 100m^2 ?
- For LS2 (2018) ?



Technology transfer : potential partners

A few industrial contact were established in the past

GEM Technology

• **New Flex (Korea, Asan City)**	Proved 10cm GEMs
• **Tech-ETCH (USA, Plymouth MA)**	Fabricated <40cm GEMs
• **SciEnergy (Japan, Sagamihara)**	Fabricated <30cm GEMs
• **Keerthi Industries (India, Hyderabad)**	Only contact
• **MicroMETAL GmbH (Germany, Mulheim)**	Only contact
• **Techtra (Poland, Wroclaw)**	Fabricated <30cm GEMs

Micromegas Technology

• **ELTOS S.p.A. (Italy, Arezzo)**	Trained on Met. and Res. MMs
• **CIREA (France, Cholet)**	Fabricated Met. MMs, trained on Res. MMs
• **TRIANGLE LABS (USA, Carson city NV)**	Fabricated Met. MMs
• **SOMACIS (Italy, Castelfidardo)**	Only preliminary trials

THGEM Technology

• **ELTOS S.p.A. (Italy, Arezzo)**	Fabricated THGEMs <100cm
• **Print Electronics (Israel, Rishon Le-Zion)**	Fabricated THGEMs

(Underlined most recent active contacts)

NewFlex (-> GEM)

- Main company located nearby Seoul (South Korea)
- Two subsidiaries : NewCretec (“next door”) and Qingdao NewFlex China
- Specialized in flex circuits, huge production capability of 60000m^2 / month altogether
- Fully automated line machines (reel to reel)

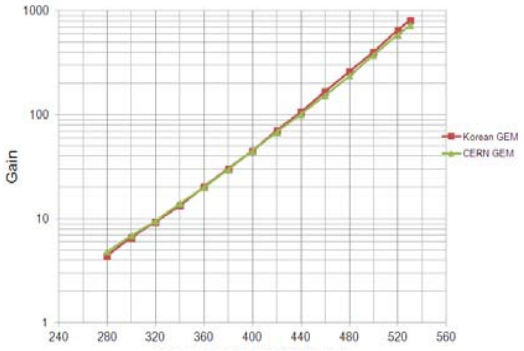
- Successfully produced first 7x7 GEM foil

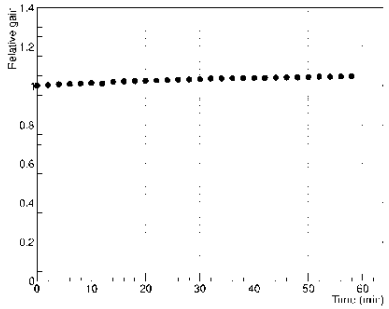
  => tested at CERN OK, June 2011
- Successfully produced 20 foils of 10x10

  => tested at CERN OK, January 2012
- Being released production of 10 foils 30x30 GEMs

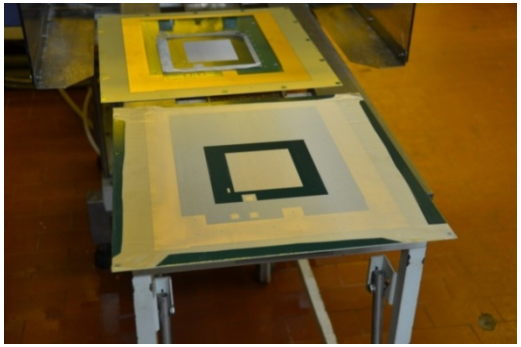
  => including foil qualification test
- Planned large samples for later

Gain vs HV

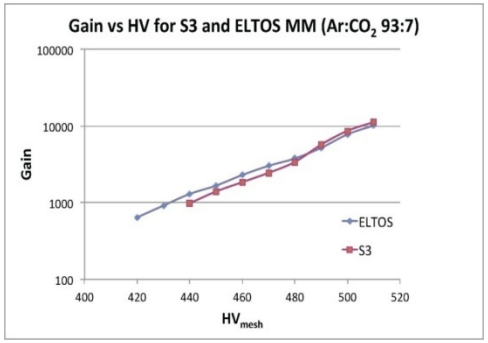




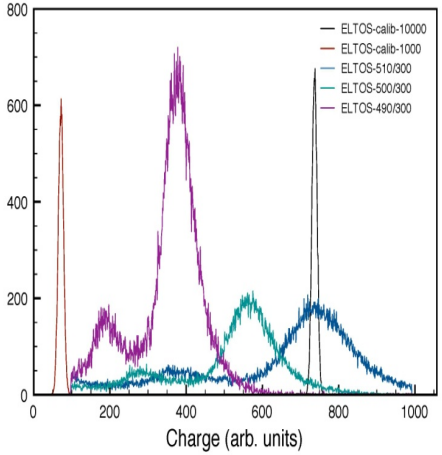
Eltos (-> Micromegas)



- Company located in Arezzo (Italy), ~100 employees
- Full fine pitch rigid process technology in house and surface finishing with large board capability up to 650x1200
- Several type of materials (FR4, Halo free, High/Mid Tg , specials)

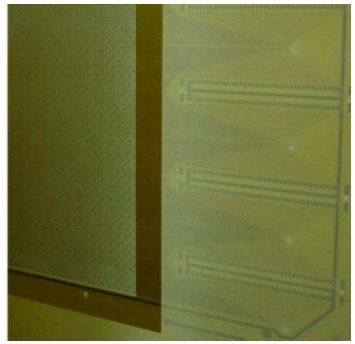


- Performed first time knowledge transfer for Met. MMs
  => November 2011
- Two 10x10 MMs “bulked” with local supervision of CERN expert (PCB and mesh stretching done by them, in-house cleaning)
- One detector has high spark rate (reason not explored) other is usable and performs similarly to CERN reference
- Planned samples on Res. MM technology



Cirea (-> Micromegas)

- Member of CIRE group (CIRETEC, SGCI, BREE, PLANTIN, CIREA and SIFELMET)
- Became part of ELVIA PCB as from September 2011.
- Very large group with 750 employees offering a complete range of PCB technologies from low cost to high end applications



- Known in the domain of Micromegas
- Reference company for CEA Saclay for Micromegas R&D
- Produced small and mid size (600x500) bulks (different flavors)
- Claims still some problems with process steps and stability
- Declares willingness to contribute to MM industrialization
- Wish to acquire full knowledge for reference MM models
- Planned samples on Res. MM technology

Techtra (-> GEMs)

- Company hosted at Wroclaw Technology Park (Poland)
- Small facility “laboratory style” with manual equipments
- Benefits of special spinoff support program
- Focused on GEM foils production, incl. framing and QC

Present status

- Produced GEMs w/double mask process for local institutes (mainly for R&D)
- Max possible size 30x30
- Today getting experience on single mask process 10x10

Future upgrades

- Being tendering to upgrade full machine set for sizeable production flow and larger size (650x2200)
- Getting larger locations in WTP for installing new machines

- CERN has provided technical consultation for new equipments
- Techtra could fit cost attractive limited series and fast prototype turn around
- Ready to be operative in upgraded configuration: probably ~end 2012

TechEtch (-> GEMs)

- US company located in three manufacture plants
- Flex circuits are fabricated next to Boston MA
- 14000m^2 and 350 employees
- Known to CERN from the past

- Already producing GEM foils
- Contact refreshed by Rui in 2012
- Declared interest to upgrade to GEM single mask process -> CERN to give instructions
- Concerning large sizes (0.5x1.2m^2) they cannot yet deal with long foils (polyimide etching)
- They are seeking collaboration with MIT for R&D money for large single mask project
- Waiting for their feedback on status of this project

CERN resources on MPGDs
Workshop production capacity

- CERN investments for R&D:
  - New equipments for large size GEM & Micromegas manufacturing (+ new bldg. 1000m^2 1Q2014)
  - Participation of 4 specialized technicians of the workshop (2 GEMs + 2 Micromegas)
  - Securing 2 technicians as staffs

- Contribution of AIDA WP9 (Advanced EU Infrastructure for Detectors at Accelerators):
  - 1 fellow for 2 years (started Jan 2012) to:

    Help installing, commissioning and setting up equipments

    Support production of MPGD prototypes

    Define test procedures for fabrication QC

- The workshop production capacity depends on manpower devoted to production

  Typical rule of thumb figure: 1 large GEM or bulk MM / person / day (~220 pcs / person / year)

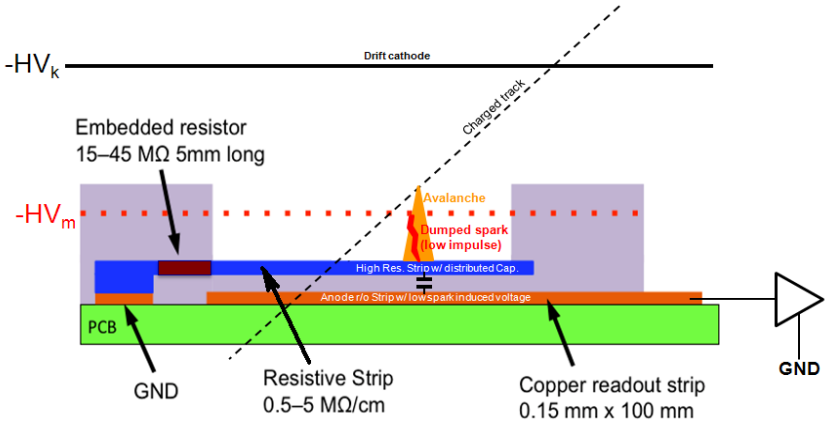
  ("prototype handling style", with knowledgeable technician, basic QC, excl. manpower for detector assembly)

  Saturation depends also from number of large concurrent projects: 2 (3 ?) maximum

Today the EM workshop can offer support to limited mass production
Priority to projects with high R&D content and technology stabilization

CERN training on Resistive Micromegas

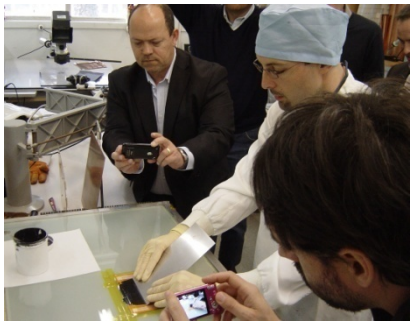
- Sparks in MMs create dead time and/or damage to detector and associated electronics
- With Res. MMs the spark impulse is highly reduced (technology developed at CERN)



- Res. MMs are the present technology for future applications (also for fewer cases less concerned with spark problem)
- CERN organized a 1+½ days training on Res MM technology to Eltos and Cirea (end March)
- Course based on theoretical explanations and practical demonstrations

1) Theory

2) Practice



3) Questions

4) Bulking

Remaining home work for Eltos and Cirea : produce samples of Res. MM. 10cm x 10cm size

Conclusions

- The work on industrialization has started with a few known companies
  It's well justified by the perspectives of large productions for GEM and Micromegas

- Needs from LHC experiment upgrades are being detailed:
  Atlas and CMS are the big clients
  Alice and LHCb (?) are a factor 10 smaller (but still not negligible)

- Plans are still preliminary and will hopefully be approved end 2012/beginning 2013
  All experiments indicate LS2 (2018) as target period
  The modalities for upgrades are still under discussion

- Despite the uncertainty of these preliminary plans, time should not be wasted
- Coordination of the industrialization efforts shall be continued
  - within RD51
  - in close collaboration with the LHC experiments
  - and with the support of the other (several) non LHC experiments
    (apologies, not mentioned here for time reasons)