Ancillary equipment: Front Tracker

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INFN – Rome and
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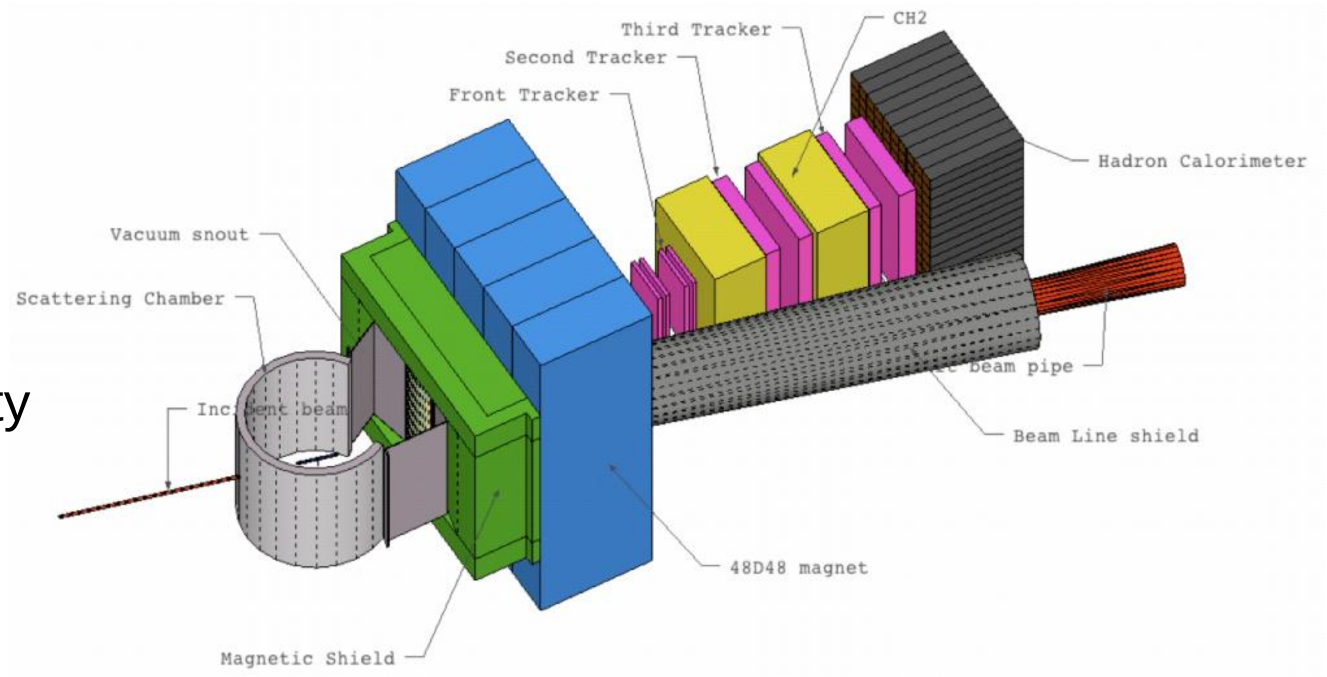
2013 –Nov – 4
SBS DOE Annual Review

Outline

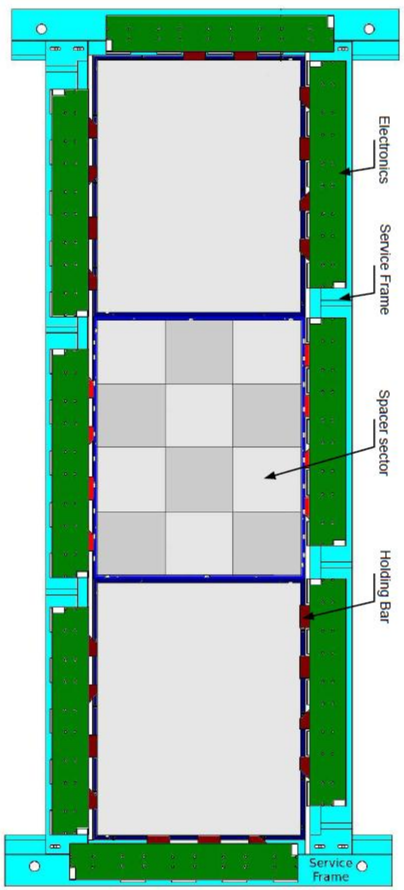
Status

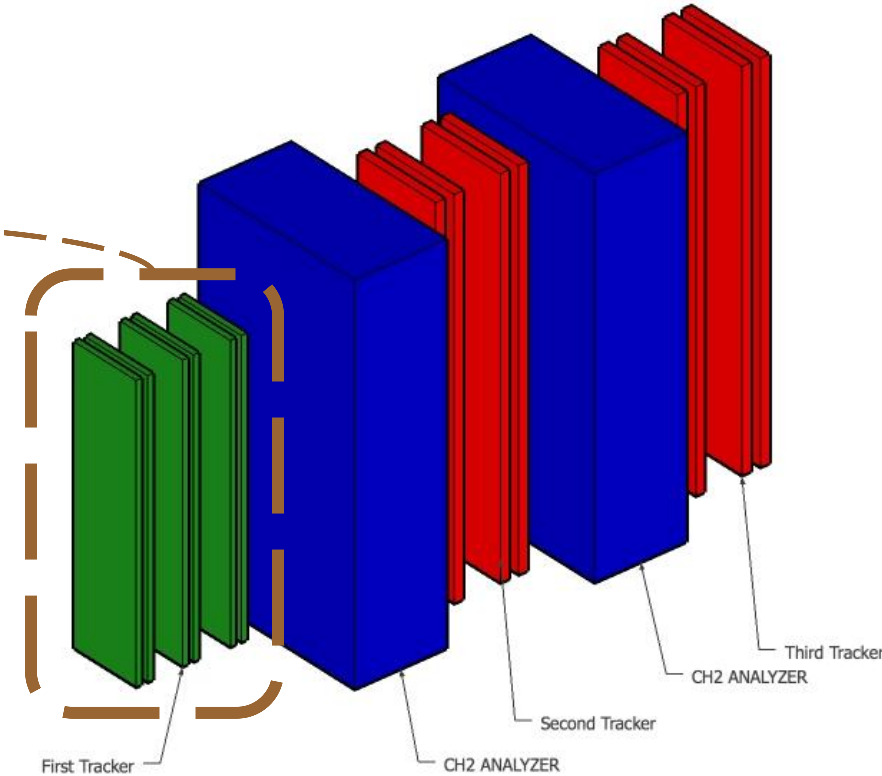
Pre-production activity

Electronics



Front Tracker Requirements





Hit spatial resolution ~ 70 μm

Stand large background (γ ~ 250 MHz/cm^2, e/π 160 kHz/cm^2)

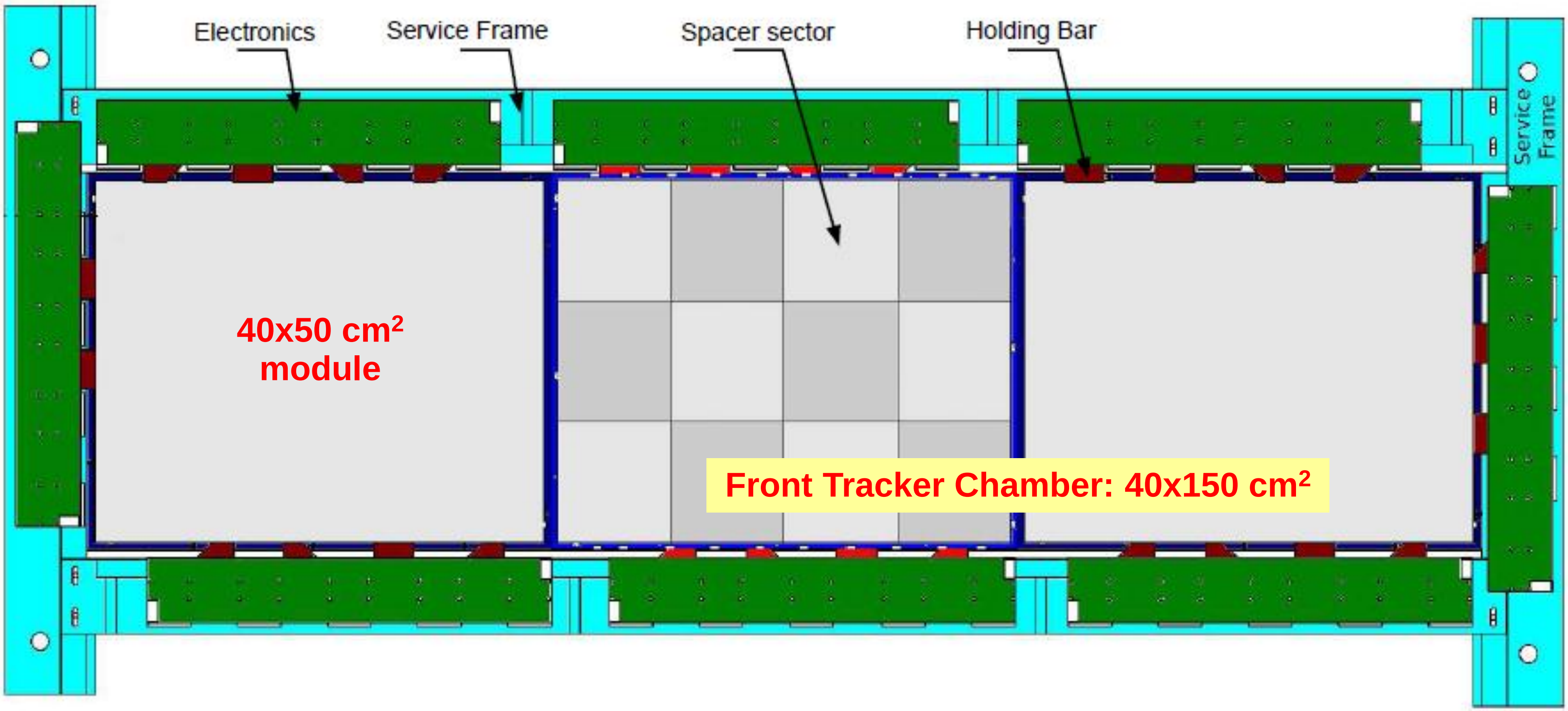
Transverse area at least 40x120 cm^2

Event rate at the level of 20 kevents/s

Reuse in different configurations (SBS/GEp5, BigBite/GEn …)

Main Technical solutions

- Use the COMPASS approach: 3xGEM, 2D readout - one significant difference: use new single mask GEM foil (instead of double mask) – cheaper and faster production
- Modular design: chambers consists of 3 independent GEM modules (40x50 cm^2) with thin dead area
- Electronics around the module, direct connection; 90 degree bending between modules
- External support frame in carbon fiber (long bars) to minimize thermal deformation



Workforce and funding

INFN Group	Researcher (Unit / FTE)	Tech. (Unit / FTE)	Role
Bari	2 / 0.5		Gas system and beam test
Catania	3* / 1.5	3 / 2	GEM module assembling, mechanics, beam test, analysis
Genoa	1** / 0.5		Electronics design and test
Rome	1 / 0.5	3 / 2	Coordination, design, test, chamber integration, analysis
Total	*7 / 3.0*	*6 / 4*	
Other support (collaboration): CERN / UVa / JLab			

*) one mechanical engineer

**) electronic engineer

INFN/Funding:

- Prototyping and Realization: 2008-2014): 800 kUSD
- Maintainance (2015-2017): ~50 kUSD/year

Schedule and Status

	2009	2010	2011	2012	2013	2014	2015
Preliminary design (include MC study)							
Prototyping							
Procurement							
Pre-Production (1^{st} chamber)							
Production							
Beam Test	Dec DESY		Sept Mainz	June CERN	May DESY		

Development phases in part affected by constraints in the flow of funding

Delivery delay of the GEM foils from CERN for prototyping and pre-production

(no significant impact in SBS, we started erlier)

During pre-production we made some fine optimization:

- GEM foil, details in construction procedure;
- one drastic change in foil quality check.

Development includes: GEM chambers, readout electronics (and related software)

Material Procurement

Front Tracker		Module	Chamber	Front Tracker	In house	Ordered
Chamber			1	6		
Module		1	3	18	3	
GEM Foils (CERN)						
Drift Foil		1	3	18	14	
GEM foils		3	9	54	35	24
Readout		1	3	18	14	
Honeycomb		1	3	18	7	10
Mechanics (RESARM)						
Frame 0 – Cover		1	3	18	20	
Frame 1 – Top		1	3	18	20	
Frame 2 – Drift		1	3	18	20	
Frame 3 – GEM		2	6	36	40	
Frame 4 – Readout		1	3	18	20	
External Frame (Plyform)			1	6		1*
Electronics (EES)						
FE		18	54	324	50	300
MPD			4	24	26	
Backplane		4	12	72	80	
Patch Panel (digital + analog)			8	48		50
Electronics Cabling (LINDY)						
HDMI 3m cable		8	24	144	80	
HDMI 20m cable		5	15	90	45	
LV cable		4	12	72		
HV cable		7	21	126		
HV Divider		1	3	18		40
LV Power Supply (6Vx20 Amp)			1	6	8	
HV Power Supply		1	3	18	24	
Gas System						
Controller + Flowmeters (MKS)				1	1	
Connectors (Legris)		10	36	212	250	
Patch Panel Gas			1	6	4	
General Patch Panel				1	2	

Most of the material already in house or procured

Remaining parts will be procured in 2014

Assembling line prepared and tested

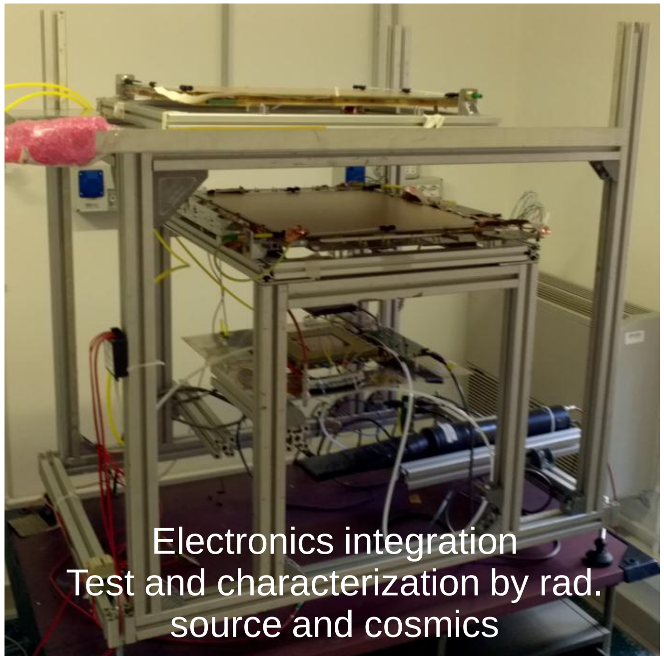
Production on the way

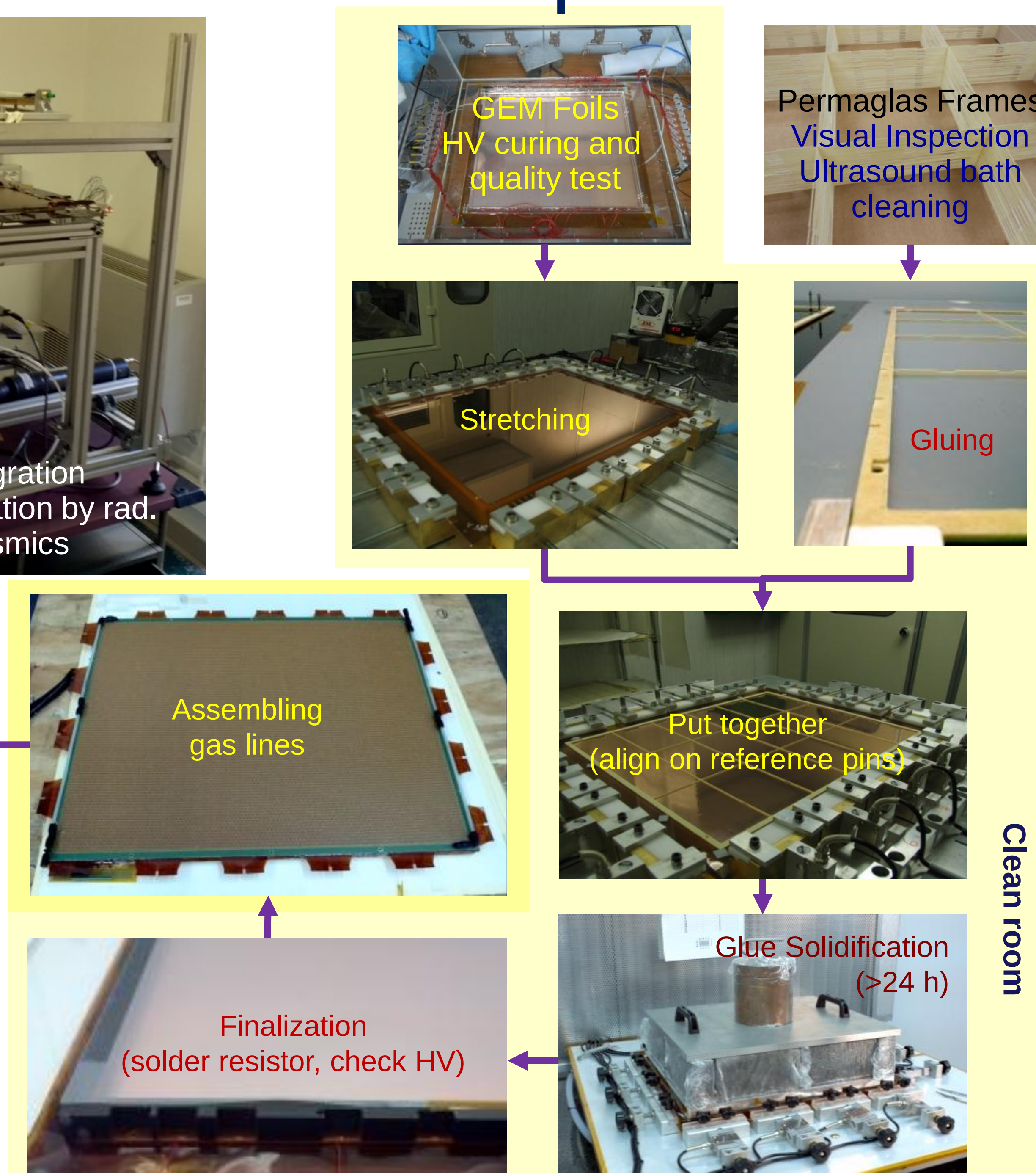
GEM Module construction process

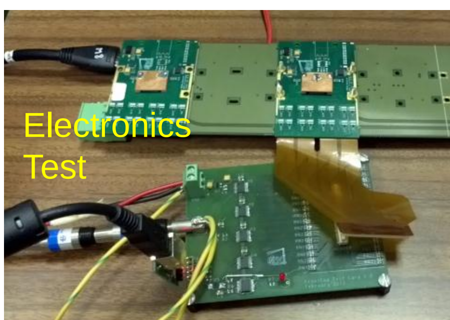
Module production fully established in Catania

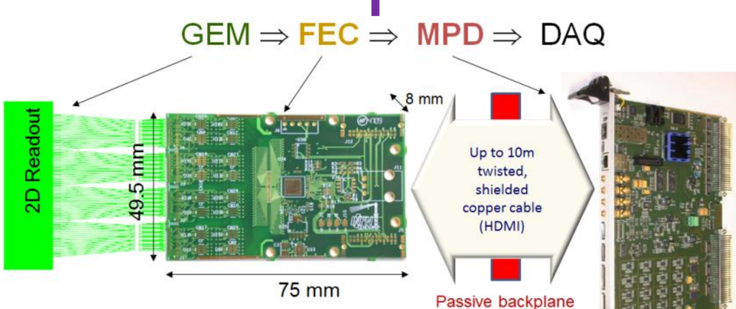
Module characterization in Rome

Production speed
1 module/month



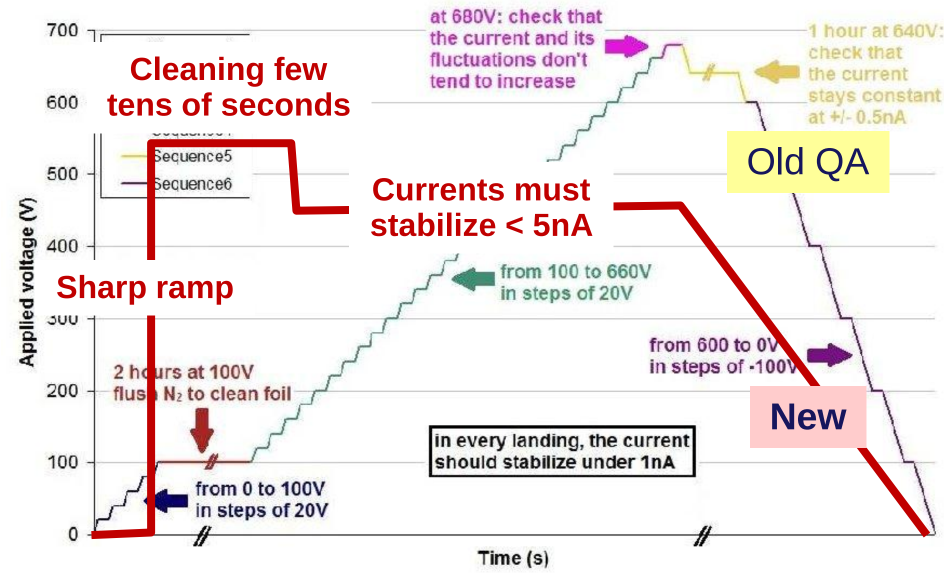






GEM foil pre-assembly test

- Nov-Dec 2012: «Standard» Quality Controls on first bunch of single Mask GEM foils was completely negative: 4 foils damaged

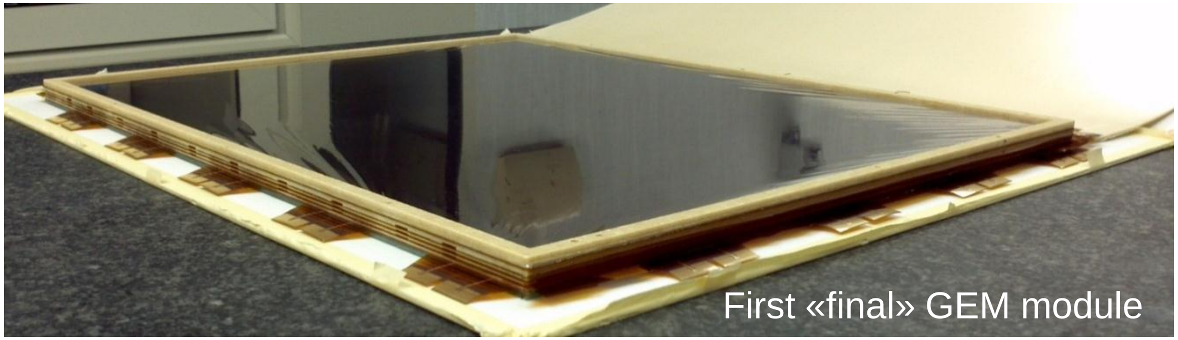


- Jan-Feb 2013: New «cleaning and check» procedure defined with CERN/Rui and UVa collaboration.
  The new procedure strongly suggest to have access to the GEM sectors HV directly to clean the foils also during/after assembling

- Since then 3 GEM modules assembled with no significant issues; small improvements adopted during assembling

- **1 bad foil of 11 analyzed with the new Quality procedure;**

- **Out of 10 accepted foils: one GEM sector of 180 compromized**

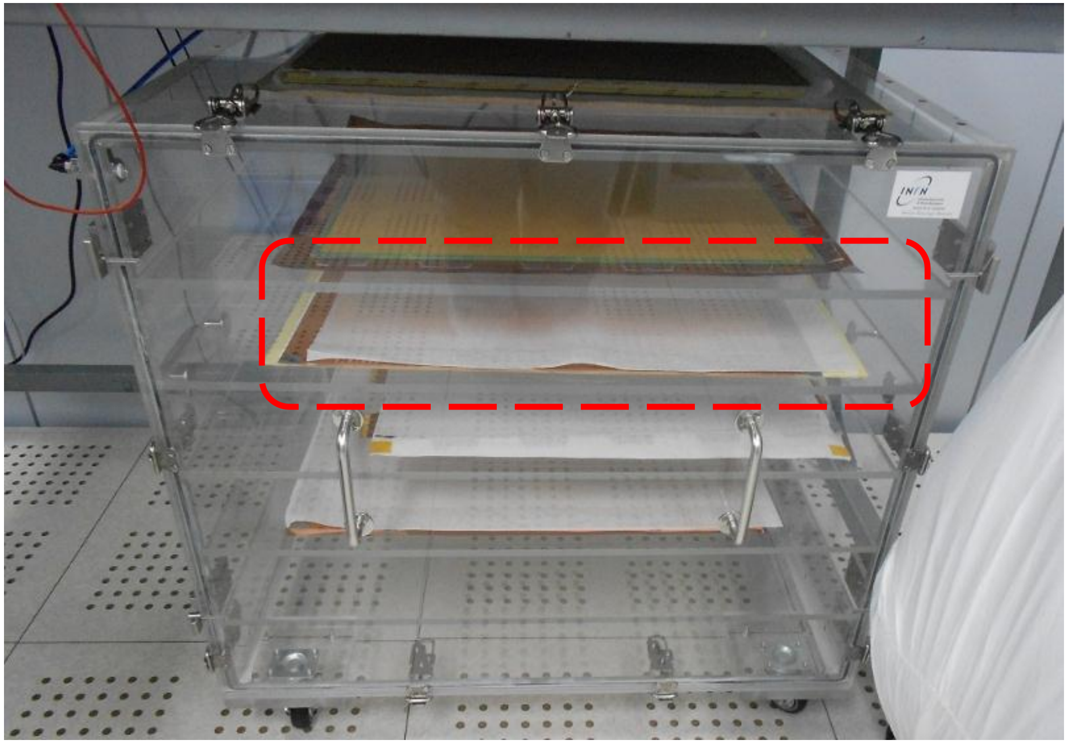

First «final» GEM module

Lesson learned: shipping and test

The first batch of foils were delivered with protective paper foil

The protective thin paper foil possible source of dust (replaced by plastic foil)

The dust from the thin paper likely the source of problem related to the first quality check procedure:



Slow HV ramp: paper dust burns up leaving carbon deposit

Quick HV ramp (and «large» current limit): dust evaporizes

Lesson learned: revised GEM foil design

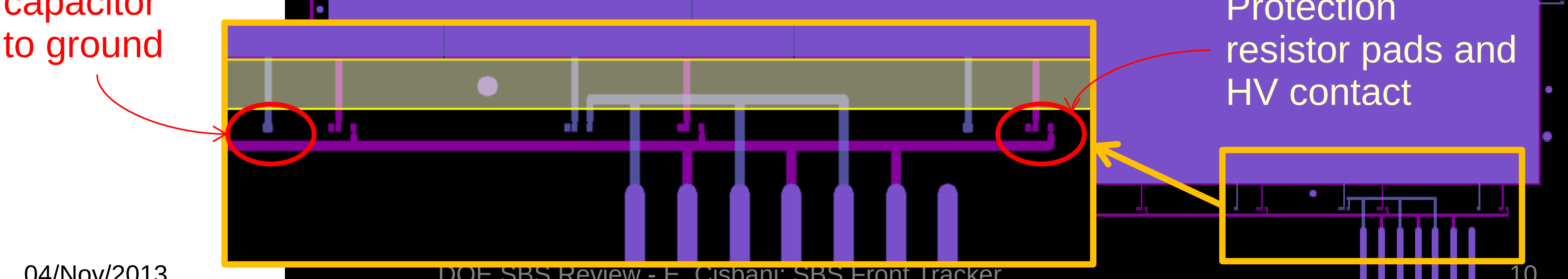
- ❑ **Resistor pads moved 2 mm out of the GEM frame**
- ❑ **Larger HV paths**
- ❑ **New pads for soldering grounding capacitors to readout plane**

Pros:

- **Access GEM sector HV directly for «cleaning» protocol proposed by Rui (even after assembling)**
- **Capacitors to grounds may improve noise level**
- **No impact on the other components**

Cons:

- Resistors are no longer protected by the frame
- Extra care in foil finishing (cutting)



May 2013: beam test at DESY

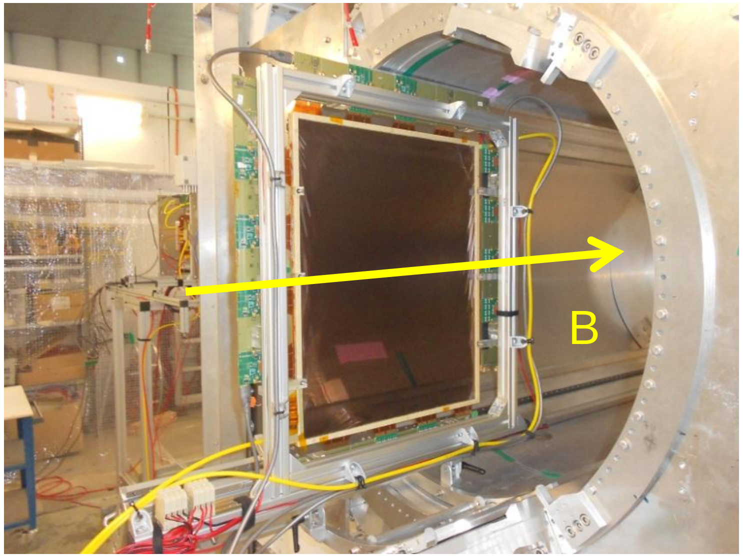
2x2 small scintillators as telescope for trigger

One big GEM in solenoid open space

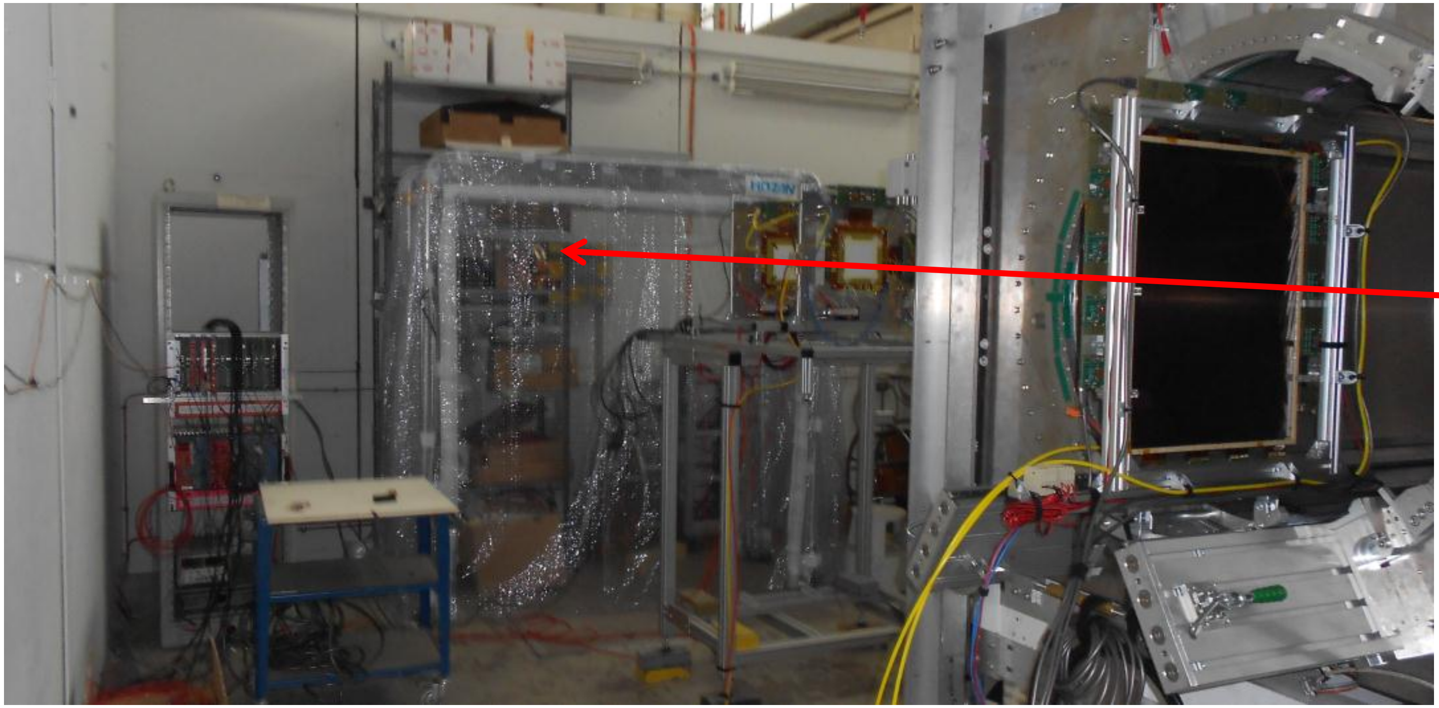
Either 2 small GEM chambers or 1 small GEM + 1 big GEM beyond the magnet as reference tracking

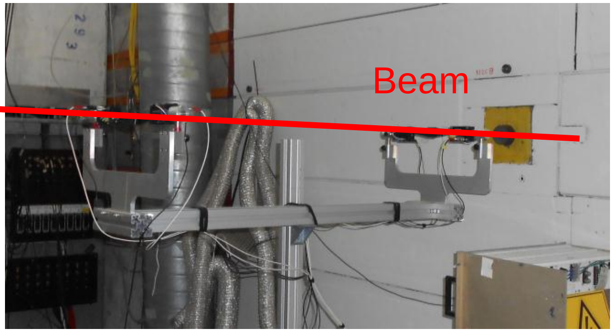
New and old electronics / long HDMI cables > 20 m total length from FE to VME

Main purpose: test overall system in «real» environment and performance in small magnetic field



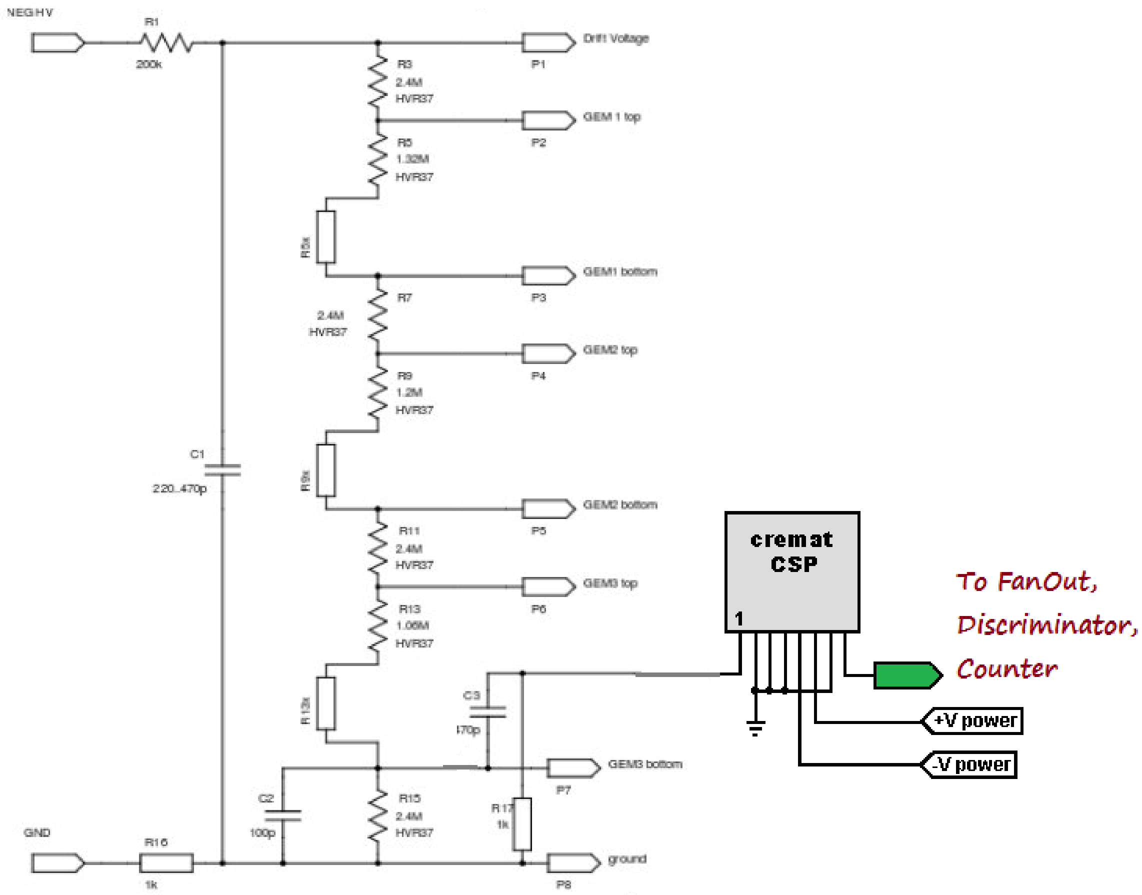
Big GEM + Solenoid

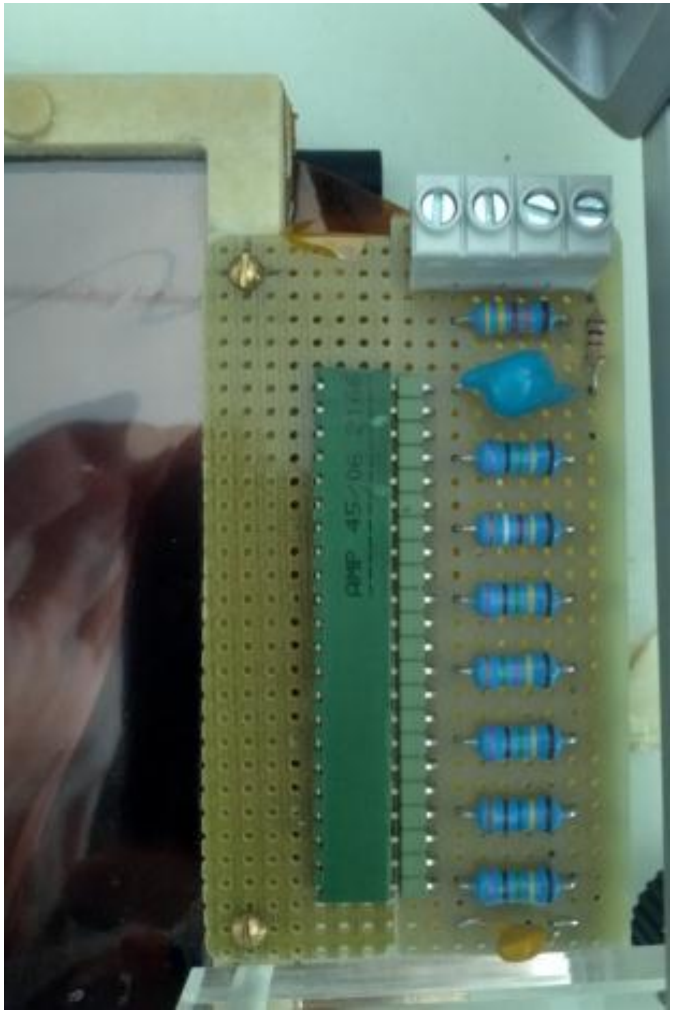




Scintillators

HV divider prototype





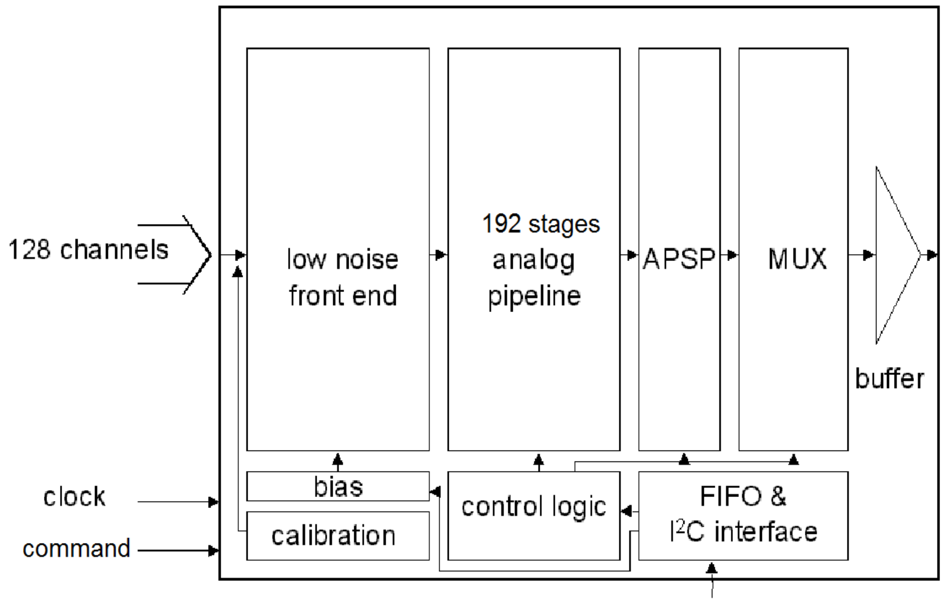
Derived from OLYMPUS

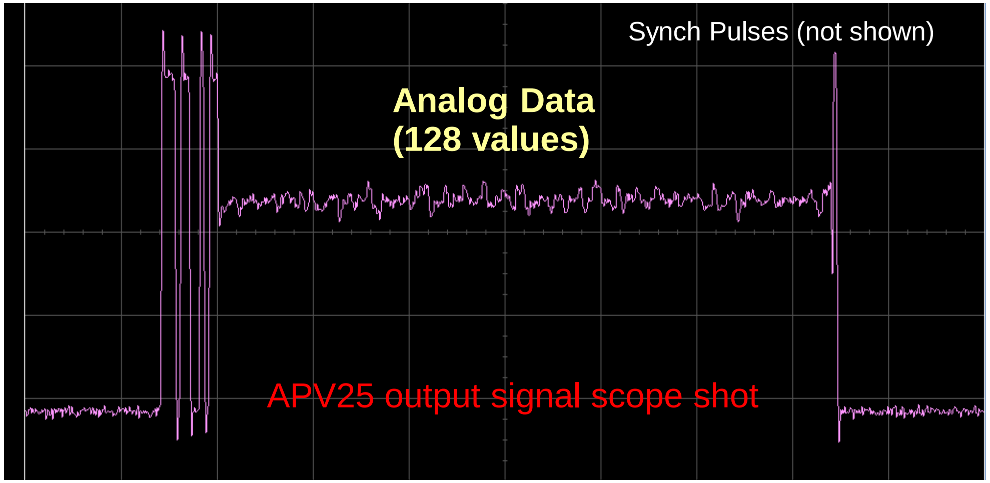
Access to last GEM plane for spike monitoring

GEM Electronics: Requirements

- High sensitivity/Low noise (typical 3xGEM gain 8000)
- Adequate trigger latency ~1 μs (wait for second level trigger) → analog pipeline
- High channel density (0.4 mm strip pitch)
- Analog readout (centroid position estimation, and better offline Signal to Noise Ratio)
- Sustain acquisition rate at the level of 20 kEvt/s

Front-end hybrid (APV25)



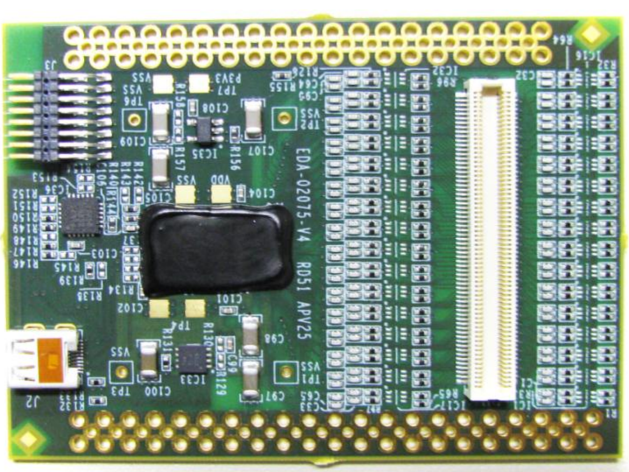


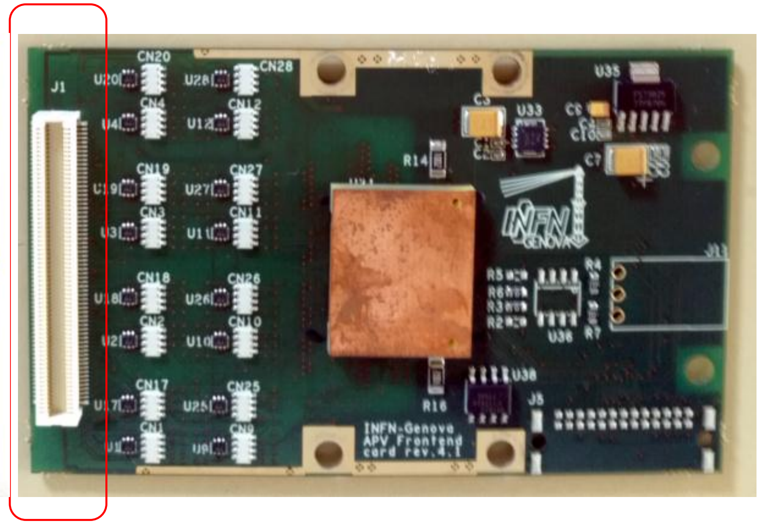
Digital HEADER (12bit)

Digital FOOTER (3bit)

- 128 analog ch / ASIC
- 3.4 μs trigger latency (analog pipeline)
- Capable of sampling signal at 40 MHz
- Radiation tolerant
- Multiplexed analog output
- Configurable / Calibration circuit

Two similar implementations



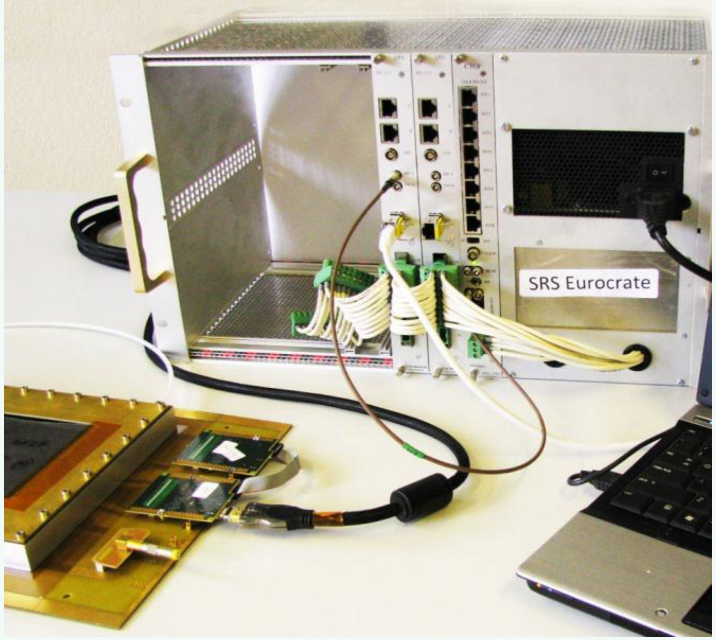
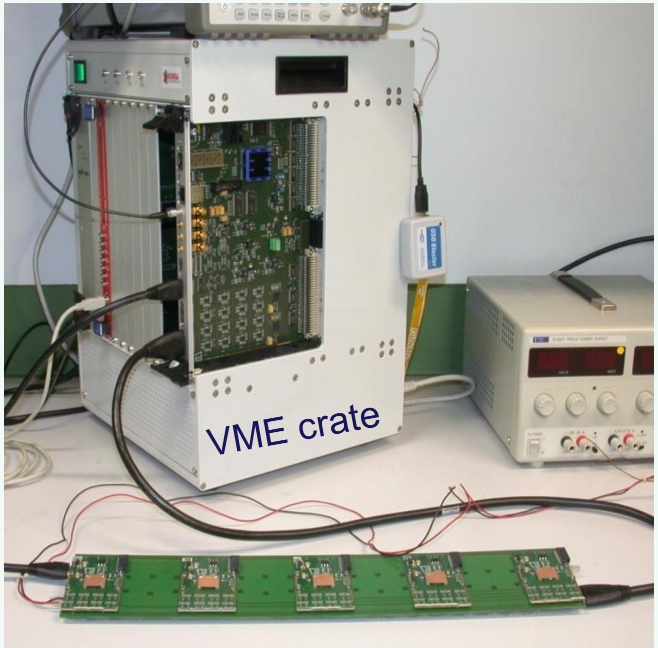


RD51/SRS

Also available with ZIF connectors

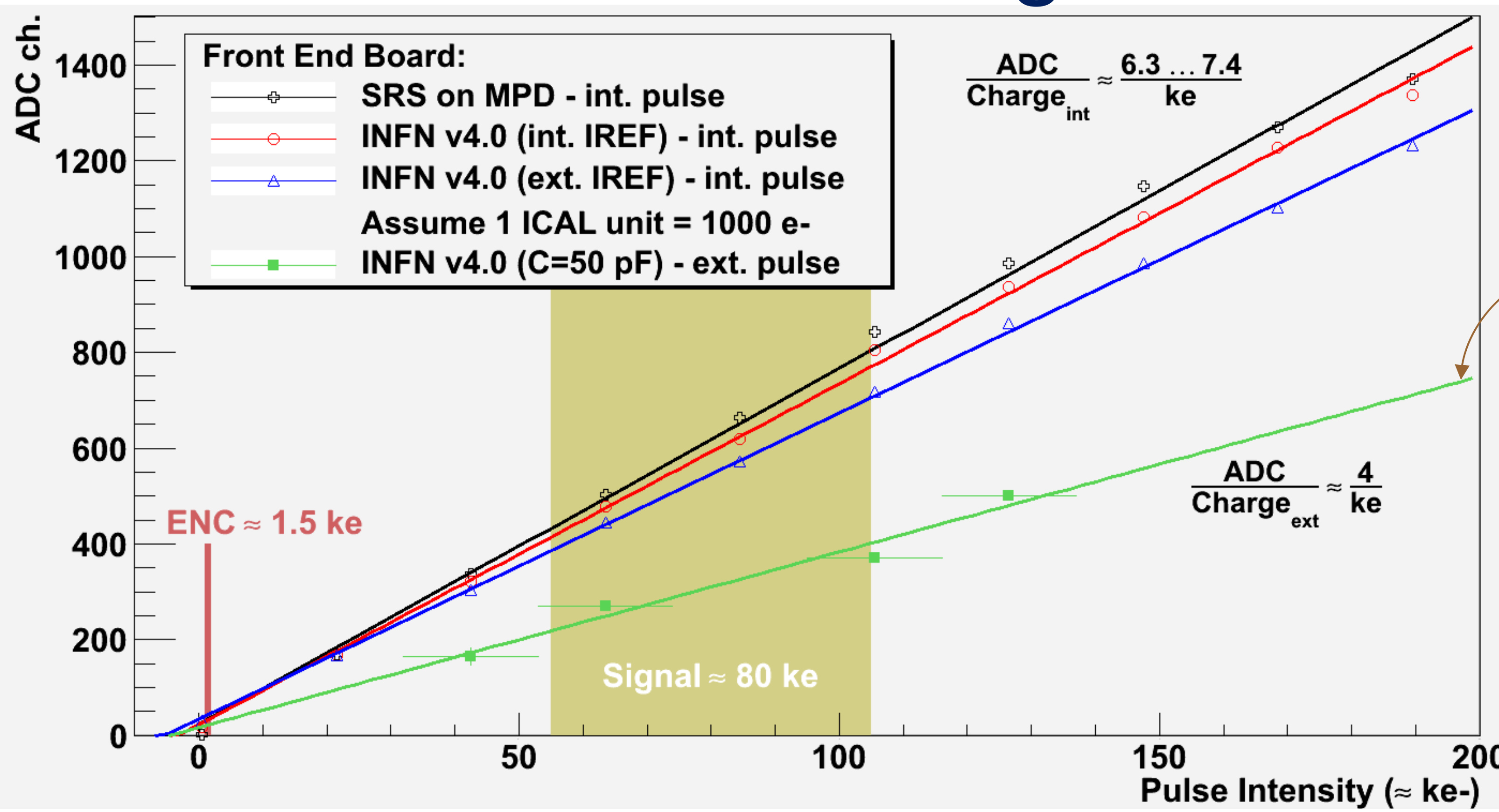
INFN

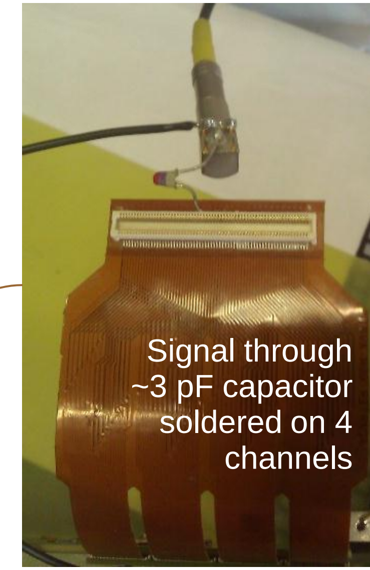
Readout Systems

RD51/SRS	MPD/INFN
	
Hybrid (APV25)⇔ADC⇔FEC⇔SRU⇔DAQ	FE (APV25)⇔Backplane⇔MPD (VME)⇔DAQ
Based on GigaBit Ethernet and EUROCRATE modules	Based on VME64x with VXS extension (JLab std.)
Oriented to flexibility, suitable for different ASIC and final applications	Custom design, designed for JLab DAQ environment

Originate from COMPASS electronics; several solutions in common.

Front-End: charge calibration





Equivalent noise performance

(in similar condition, using MPD electronics to read SRS hybrid)

Comparison on GEM module underway

(INFN/FrontEnd recently available with Panasonic connector)

Readout Electronics Status

Opportunity of 2 different implementations; helpfull for improvement and better undestanding

INFN/MPD

- designed for SBS front tracker and JLab DAQ;
- first version succesfully used in the OLYMPUS experiment;
- reviewed October/2012 by fast electronics and DAQ experts

RD51/SRS:

- more generic purpose;
- supported by CERN;
- large community

Both seems to offer similar performance; comparison under finalization.

Final Report will be prepared by Uva

Front tracker will be equipped with the INFN electronics

From the analysis point of view both electronics produce identical type of data (are interchangable)

Software

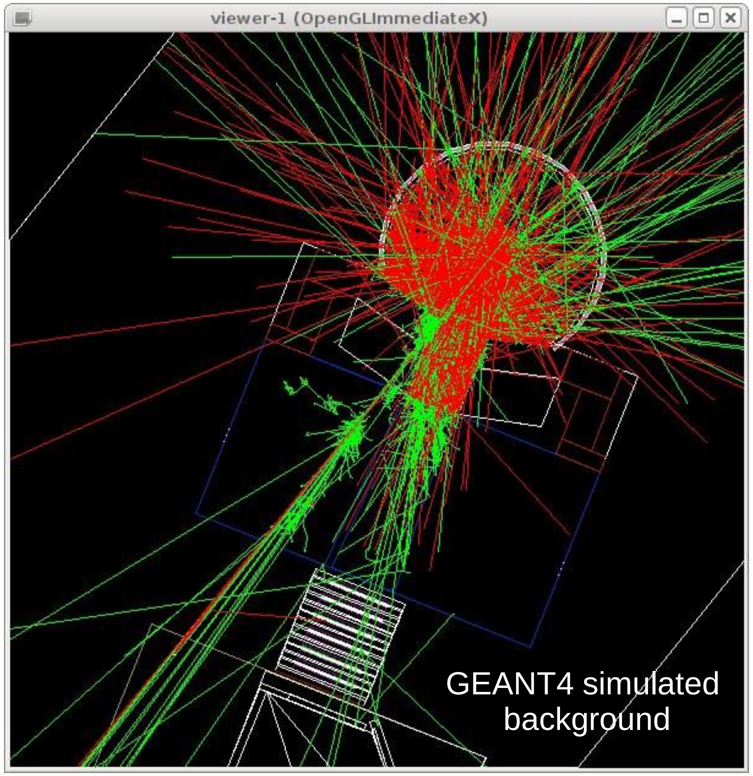
MC simulation based on GEANT4

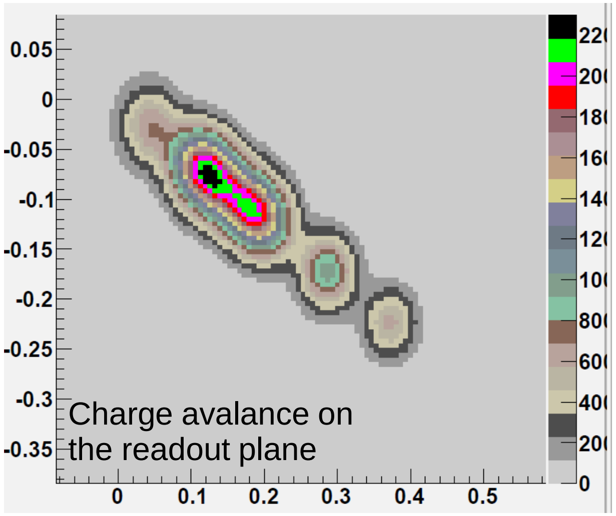
GEM response modelled (through empirical formulas) and signal digitized

Analysis software (used in tests) based on ROOT

Working on rubust analysis tracking system

DAQ software based on C++ / portable library integrated in JLab DAQ (and other systems)

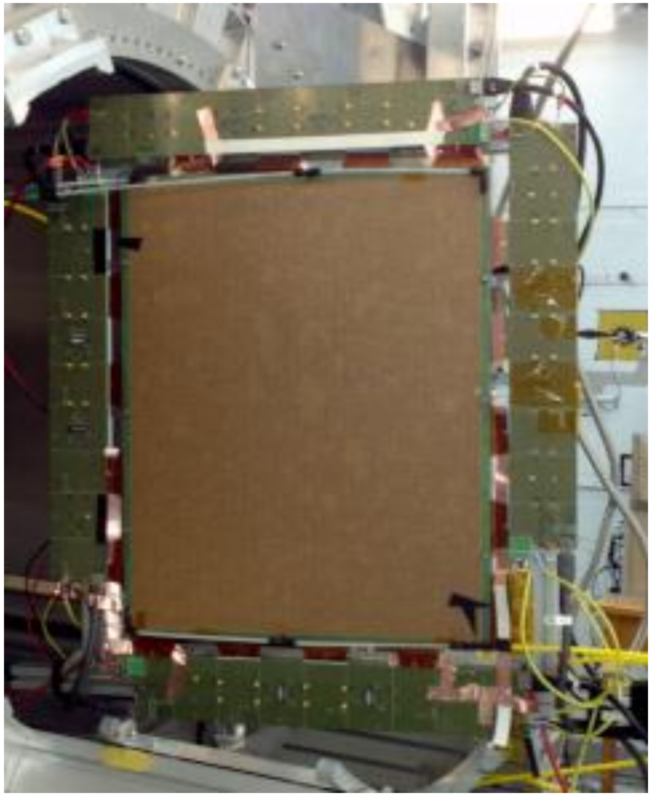




Many pieces of software already available

INFN continues to work on the analysis software

INFN Plan



First «pre-final» GEM module + Electronics

Continue GEM module assembling:

- 3 modules assembled, characterization underway;
- expected construction rate: 1 module/month
- 3 complete chambers (9 modules) by the end of 2014
- rest of the chambers by the end of 2015

Continue Electronics production and testing:

- All MPD modules produced (test underway)
- Front-End Cards ordered: ready for testing starting from Jan 2014 (will be delivered in 3 bunches)
- by June 2014 firmware optimized and consolidated

Chamber integration

- Mid 2014: start integration test in Rome
- final integration at JLab, GEM modules shipped separately

Conclusions

- GEM modules production process established
  - Fine tuning optimization on single mask foil implemented
  - Few components (HV divider, external frame) under finalization
- INFN/Electronics in production
  - quality checks procedure consolidated
  - firmware optmization underway
- Software development
  - Continuous «background» activity