CBM detector and electronics tests at COSY in 2017

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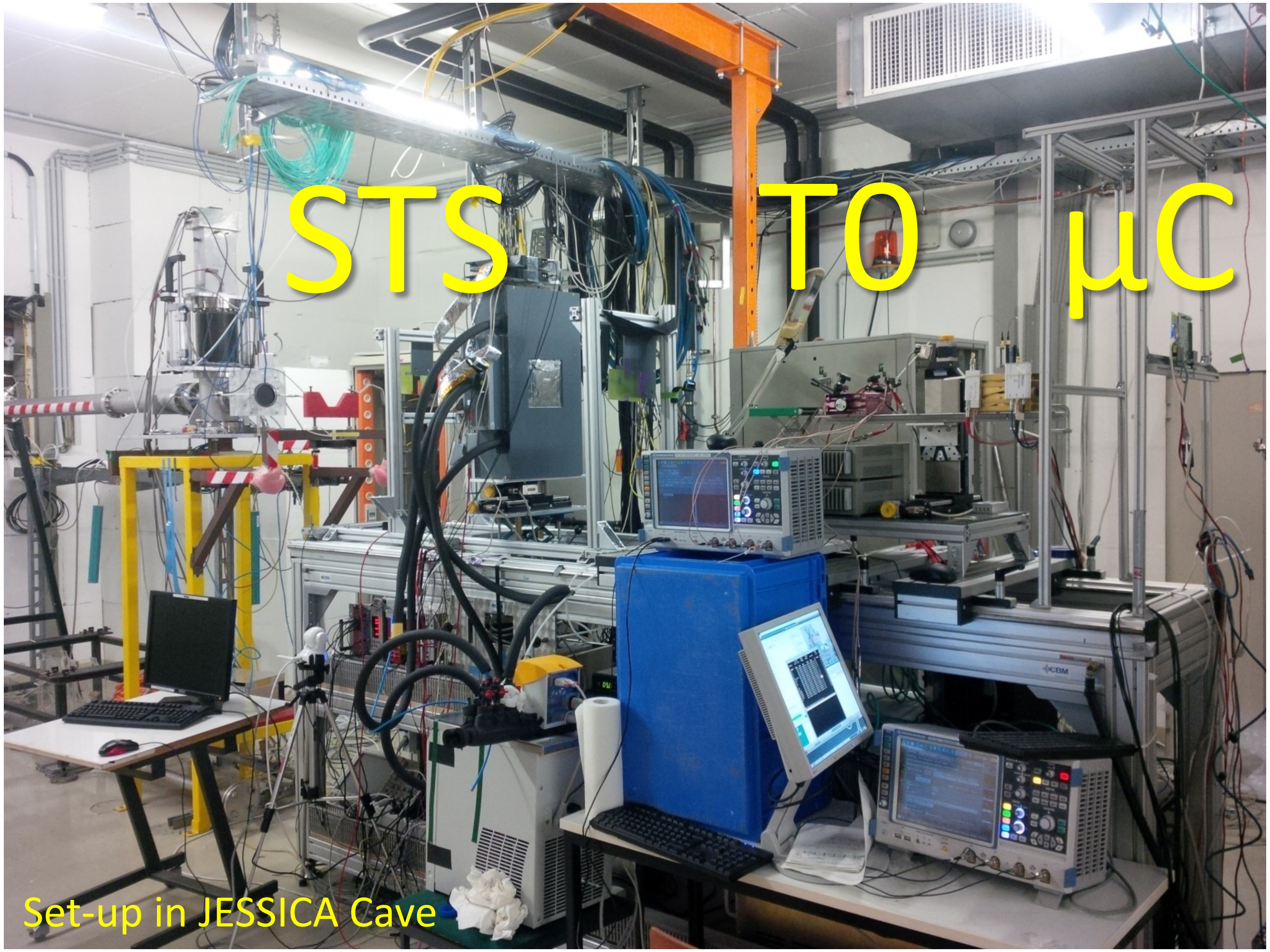
for the CBM Collaboration

5th COSY Beamtime Advisory Committee Meeting,
Bad Honnef, 19 December 2016

Outline

1) Results from in-beam tests, August 2016
2) Application for beamtime in 2017:
   I. Electronics tests: Feb. 2017 *(1 week)*
   II. Detector tests: May 2017 *(2 weeks)*

1) Results from the in-beam test, August 2016



I. Microstrip sensor studies for CBM-STS

Prototype silicon microstrip sensors:

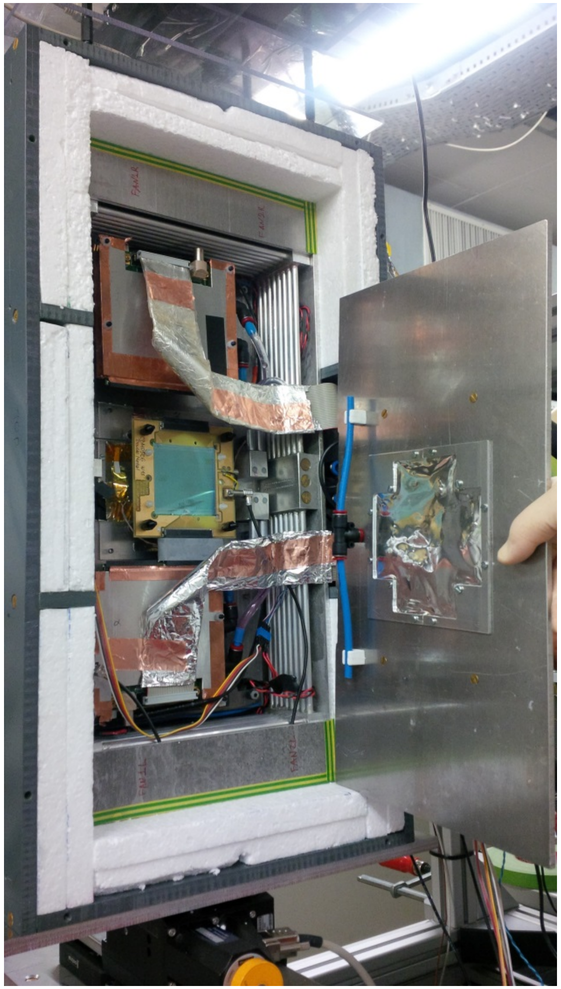
- non-irradiated (“non-aged”)
- operated under anticipated conditions:
  bias voltages > 120 V, T $\leq$ -5 °C
- read out with standalone front-end ASIC and DAQ:
  Beetle chip/Alibava system
- simple trigger: two scintillators in coincidence

Proton beam from COSY:

- Ekin = 1 GeV $\pm$ 0.01% in August 2016
- $\cong$ 5% higher energy loss in Si than MIP
  → taken into account in data analysis

Enabled us to measure:

- charge collection
- signal dependence on beam incidence angle
- cross talk etc.

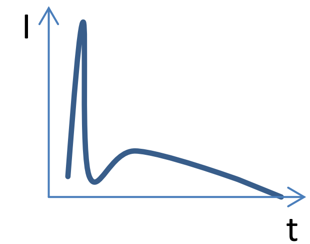


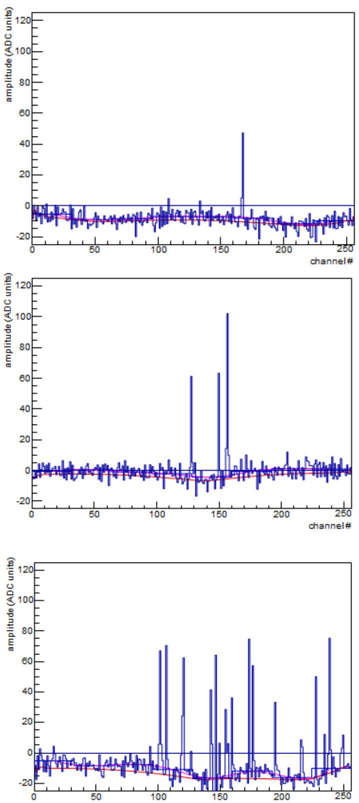
STS results on charge collection

three event classes, probably related to beam spill structure:

beam intensity time structure:

- *sharp spike:* 7×10^7
- *bulk extraction:* 2×10^8
- *spill/inter-spill:* $20\ s/10\ s$

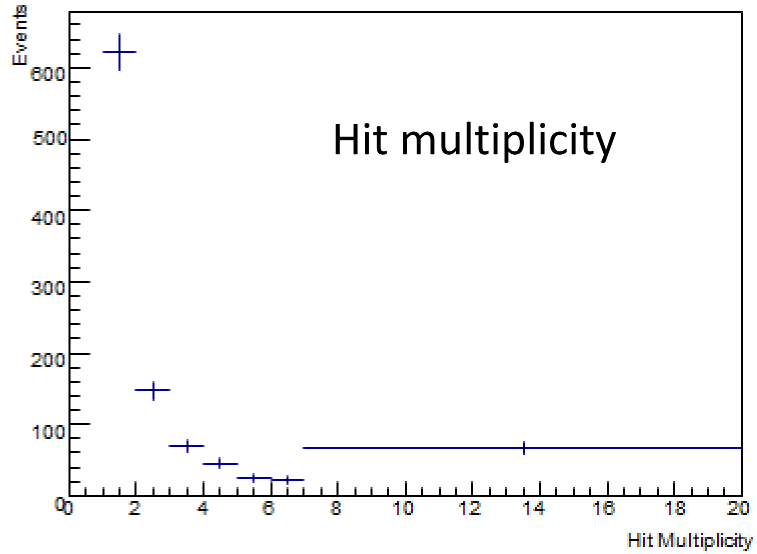




single hits

few hits

many hits



ca. 50% of the events recorded are “analyzable” (i.e. of low hit multiplicity)

Aibava setup based on the Beetle chip:

- 2×128 r/o channels
- 40 MHz analog rate
- 128 per chip analog memory stack
- **4 μs digitization rate**

data storage rate via USB to PC: ≈ 1 kHz

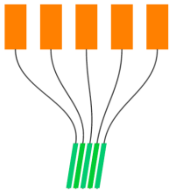
connection schemes:
strip : r/o channel

$\Phi = 0°$
all cluster sizes

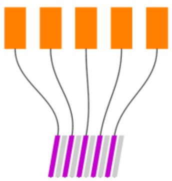
90 ADC

$\Phi = 25°$
all cluster sizes

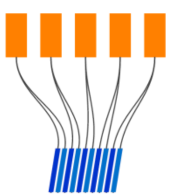
100 ADC



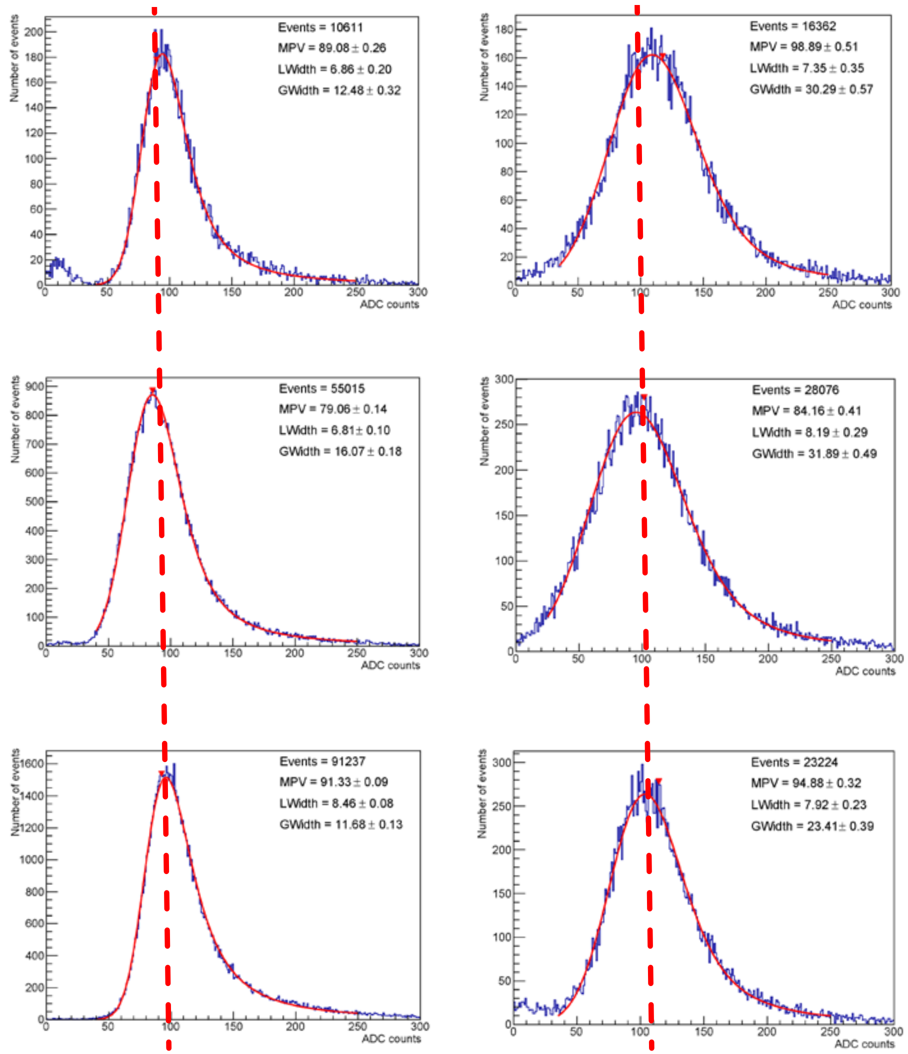
1 : 1



every second strip read out



2 : 1



Charge collection study:

- Three connection schemes between sensor strips and ASIC channels
- Beam incidence angle $0° \leq \Phi \leq 25°$ (inclination corresponds to STS acceptance
- Detailed charge collection study made

Findings:

- Size of clusters increases with beam incidence angle as expected by geometry
- For large clusters the noise increases (larger capacitive effect, as expected)
- Spectra broaden with increasing angle

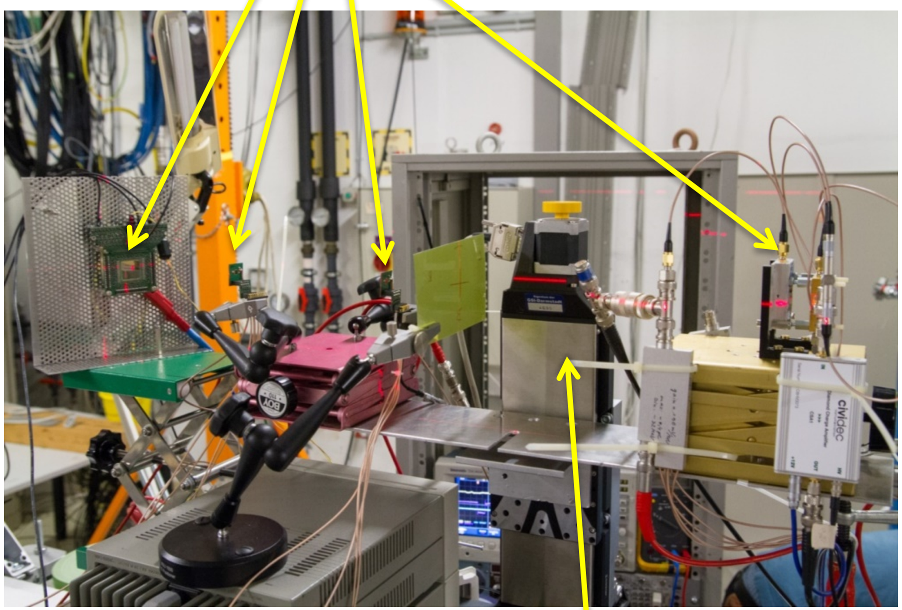
II. Diamond detector studies for TOF-T0

Main aim: Response of poly-crystalline CVD diamonds to MIPs

- Detection efficiency for MIPs in pcCVD diamond material
- Timing properties of pcCVD diamond material

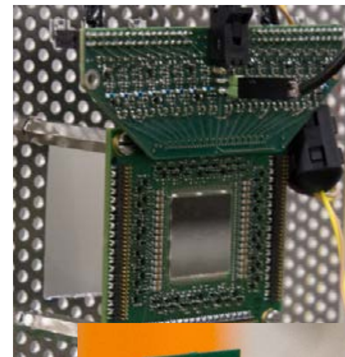
Diamond detectors (aligned via laser)

proton beam 1.7 GeV/c

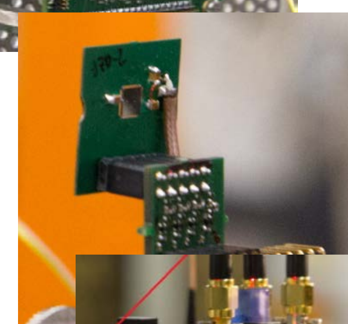


Remote Oscilloscope as flexible read-out and DAQ

Movable platform (X/Y) with µm precision



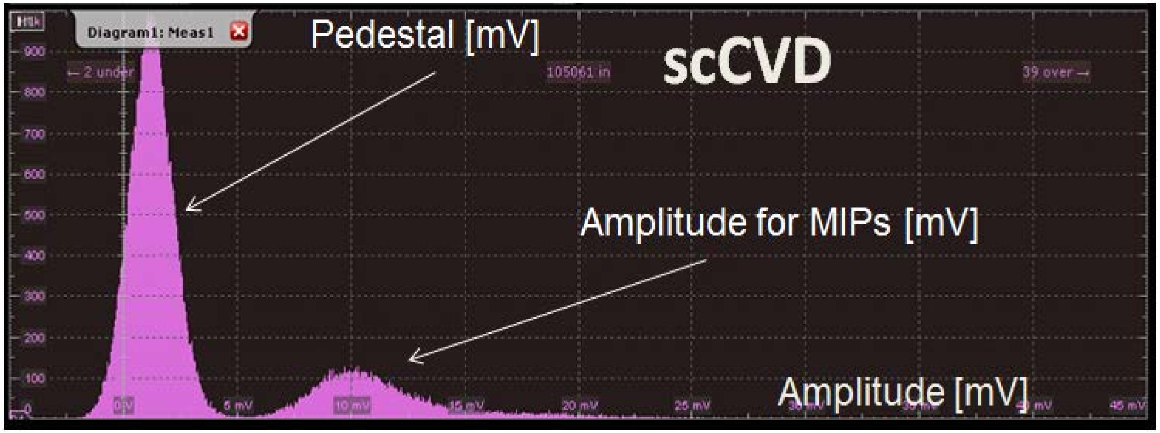
poly-crystalline (pcCVD)



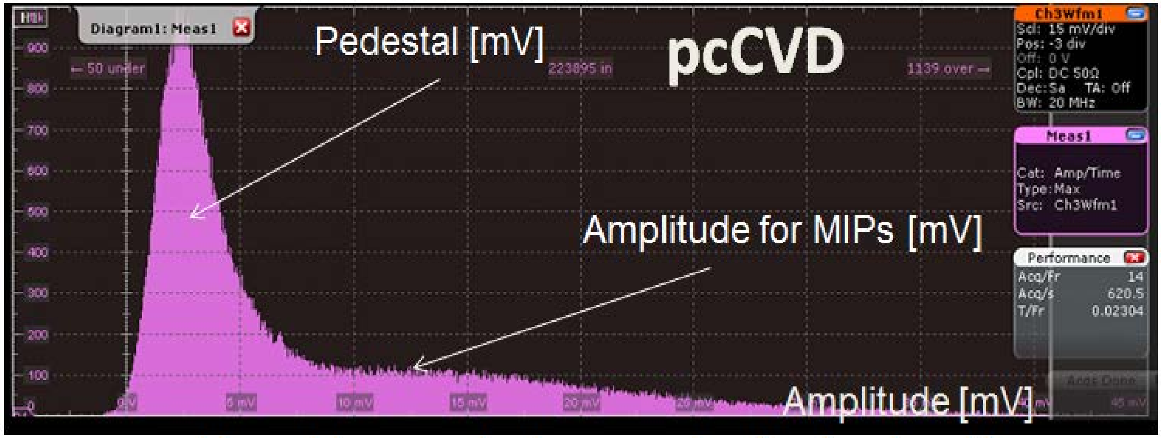
single-crystal-line (scCVD)

quasi-single-crystalline (Diamond on Iridium, DoI)

Results: scCVD/pcCVD amplitude spectra

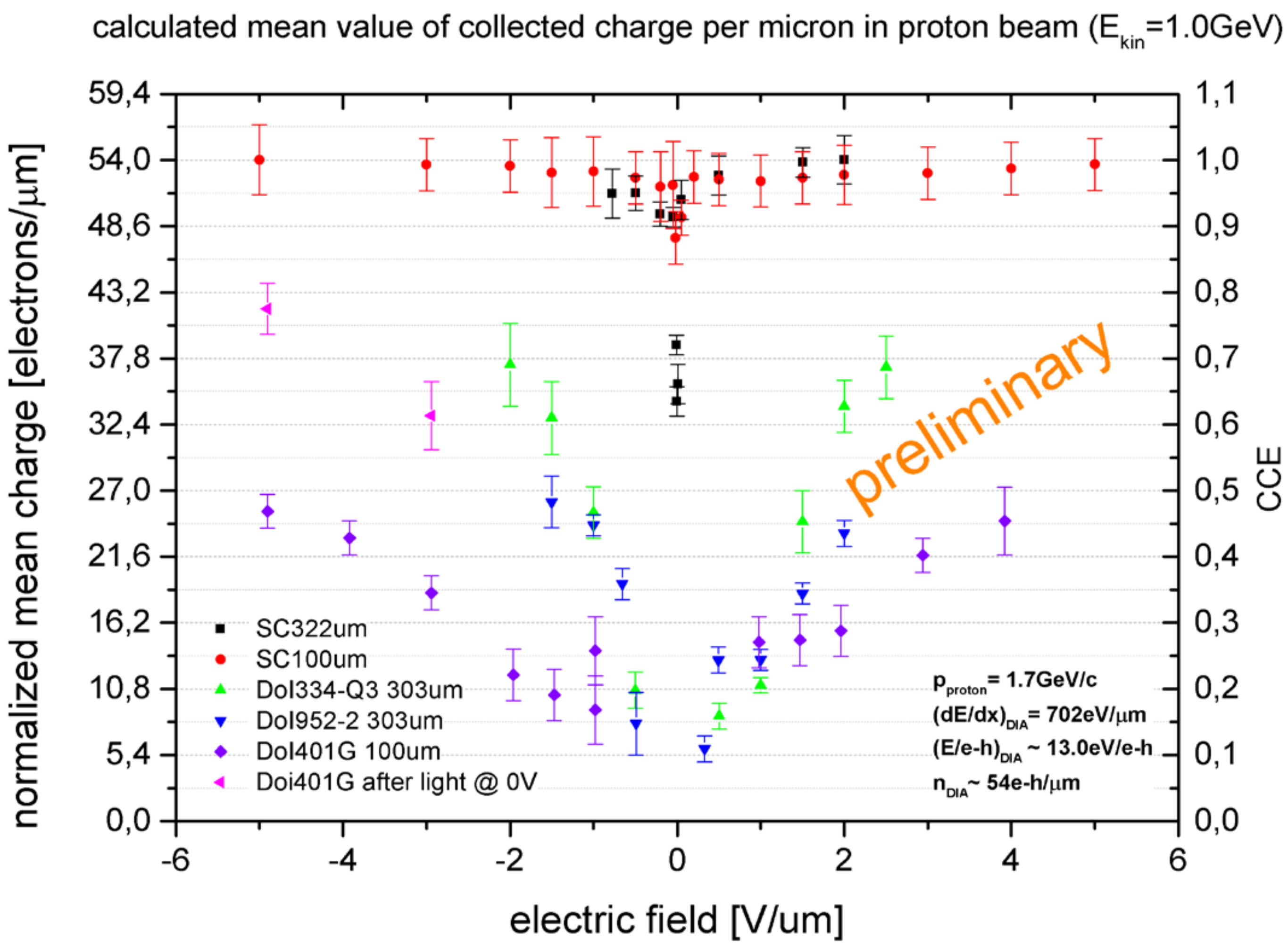


clear separation between signal and pedestal for scCVD

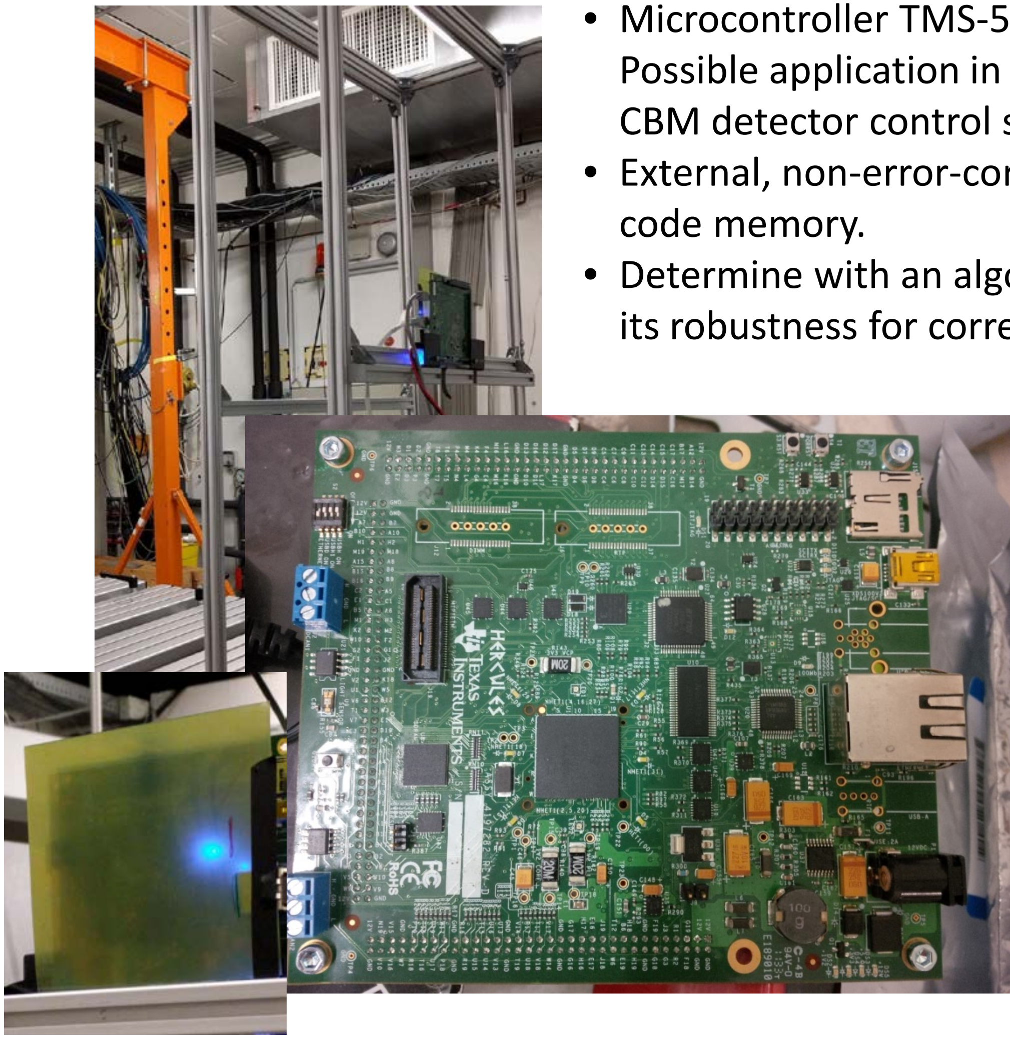


problem with separation of signal and pedestal for pcCVD
→ further tests at higher bias voltage needed !

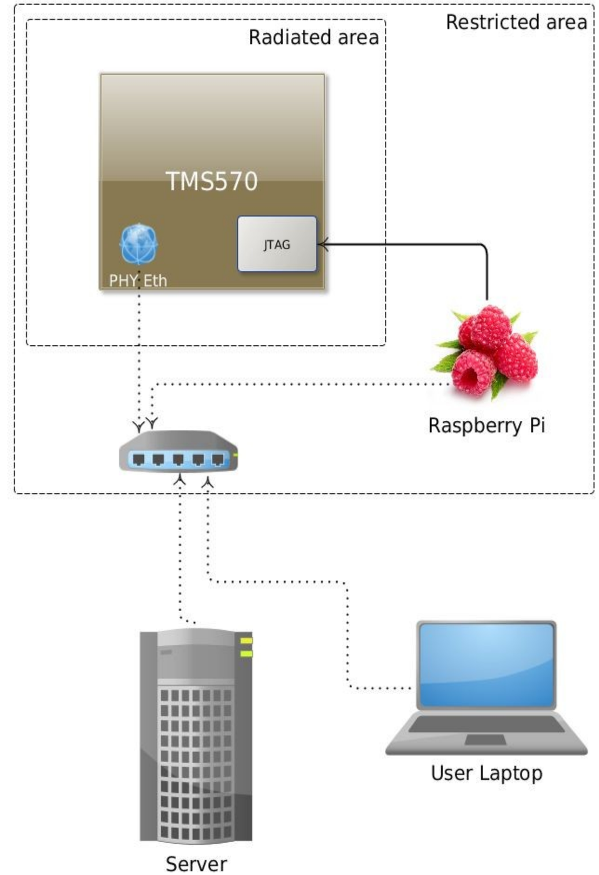
Results: DoI charge collection



III. Micro Controller rad-tolerance study



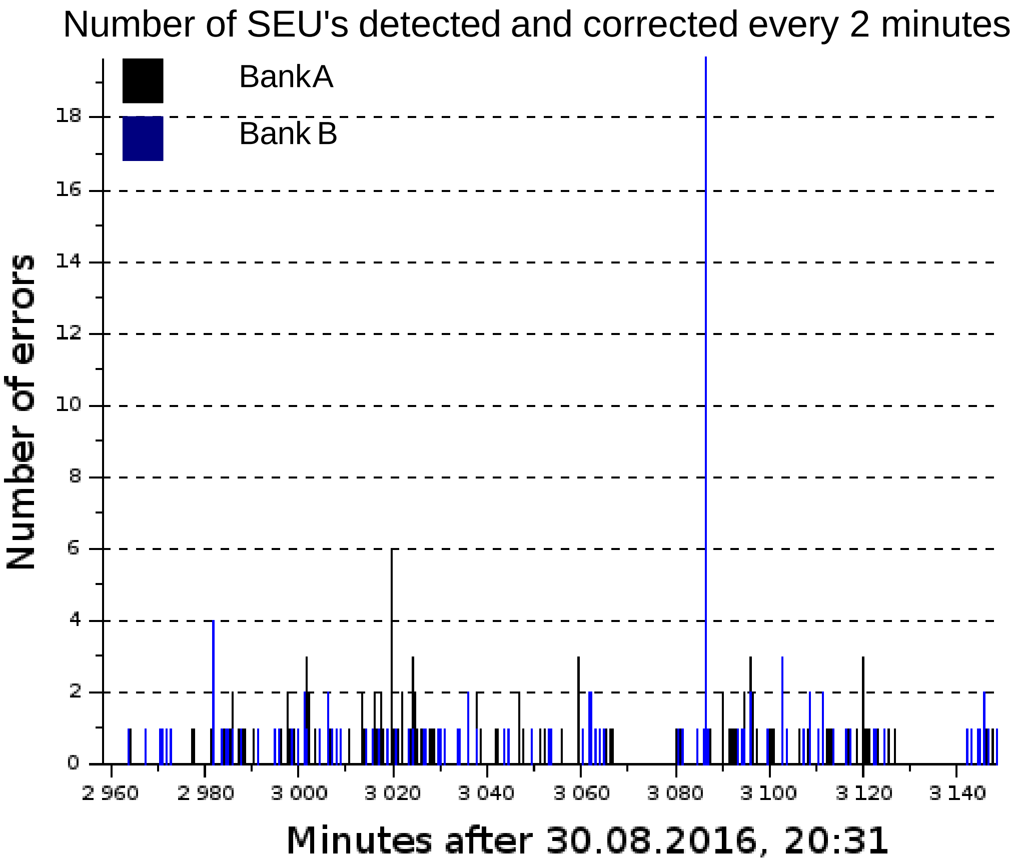
- Microcontroller TMS-570: Possible application in the CBM detector control system
- External, non-error-correcting-code memory.
- Determine with an algorithm its robustness for corrections.



- EPICS monitors failure registers
- mysql data base, every 2 seconds

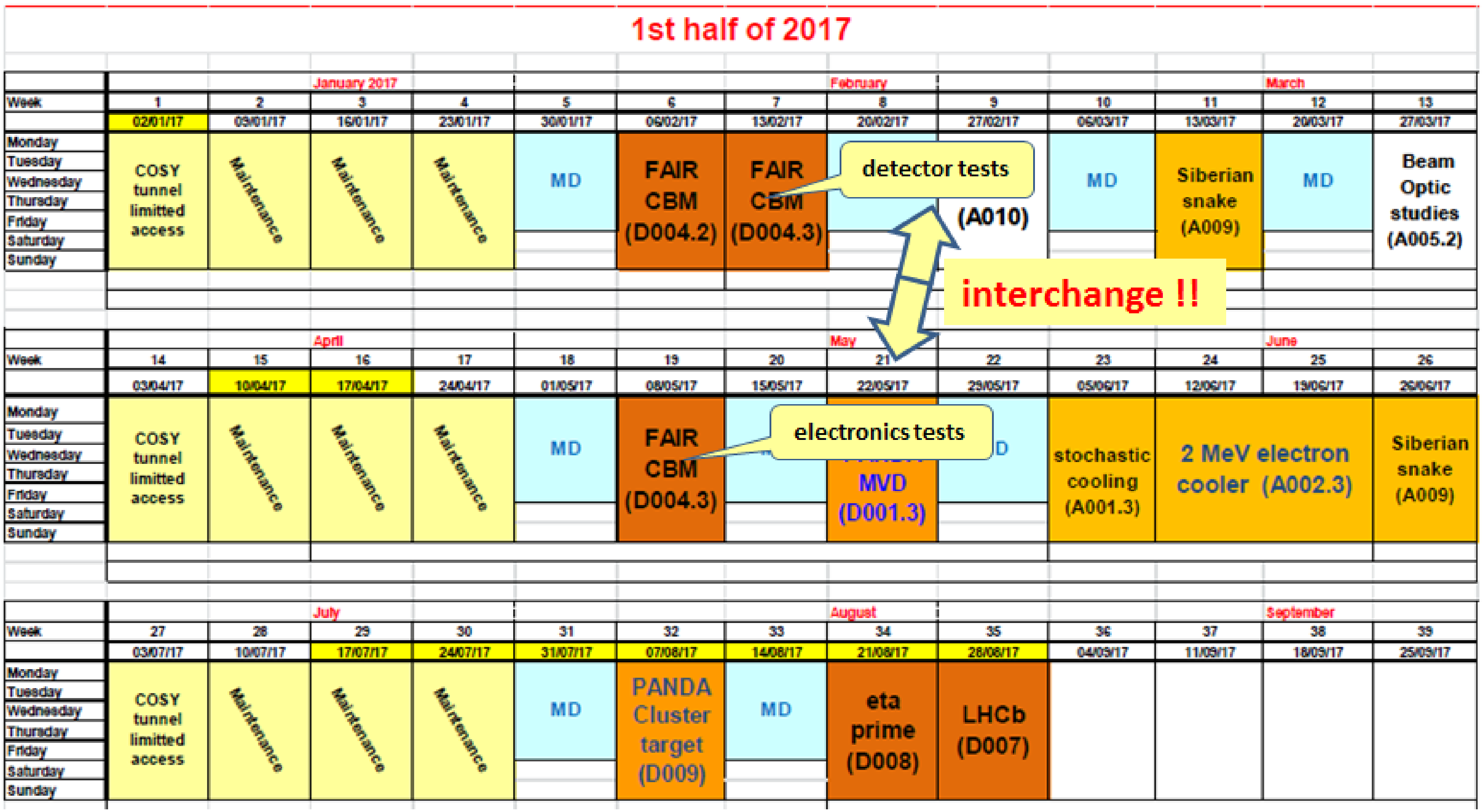
Microcontroller SEU results

- Total BeamTime: ~13 h
- No failures detected during beam-off times
- Single bit errors detected when beam was on
- No Multiple-bit errors
- Total detected and corrected SEUs:
    - in SRAM Bank A: 718
    - in SRAM Bank B: 686
- Dosimetry foil evaluation pending (offered by O. Felden et al., FZJ-IKP)



Team members from GSI, FAIR, Univ. Frankfurt, TU Darmstadt

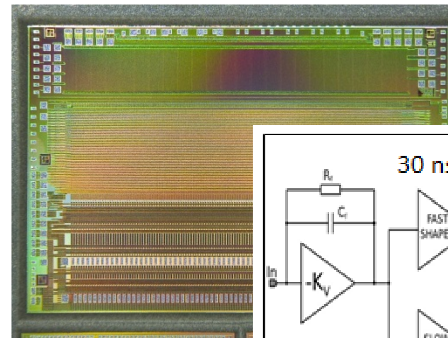
2) Application for beamtime in 2017



draft, July 2016 – to be endorsed in CBAC#5, 19-20 December 2016

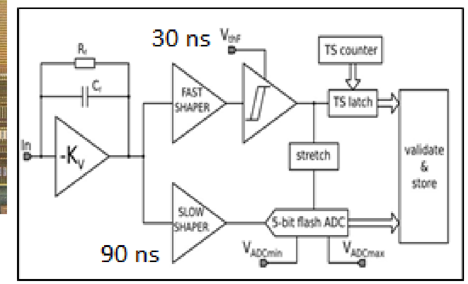
I. Tests of electronics

- STS-XYTER v2 ASIC (front-end chip for CBM-STS and MUCH detector systems) produced in September 2016.
  Detailed tests ongoing, running set-ups in the laboratory. **Ready for beam test!**



128 channels

STS-XYTER v2

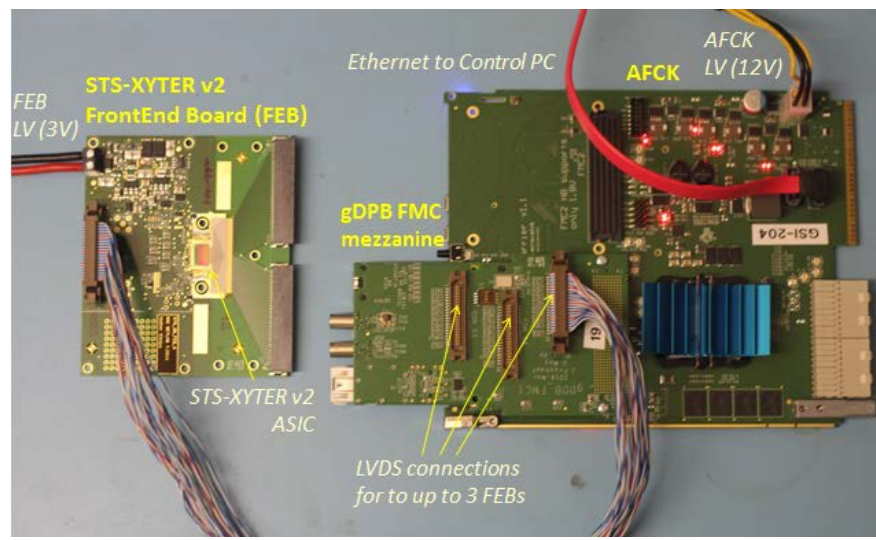


per channel: two-stage internal trigger

adapted to high capacitive load

back-end GBT compatible

- Aim of in-beam test:
  Qualification of the improved DICE cell architecture with respect to Single Event Effects (SEE) in the STS-XYTER v2 ASIC
  - *Comparison with the cross section determined in the STS-XYTER v1 test, 9/2015 at COSY, using a similar setup.*
  - Requirement:
    1 week of highest possible beam intensities in JESSICA Cave to yield sufficient statistics of SEUs



SEE results 9/2015 and expectation for 2017

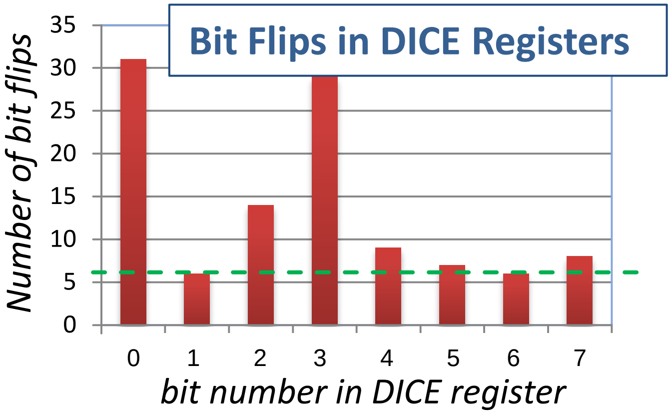
Procedure:

- comparison of 2-dimensional array (channels, discriminators) of registers implemented with **DICE cells** and regular **flip flops**
- continuous **readback** of predefined pattern or – constant – random values
- check for **bit flips** in register values

SEE Counts		~ 48 hours of effective irradiation (Sep. 2015 conditions)		
	STS-XYTER v1 (Sep. 2015)		**STS-XYTER v2 (estimate)**	
Type	**No. of bits**	**Total number of SEE**	**No. of bits**	**Total number of SEE**
Flip Flop	32240	**3467**	56420	6067
DICE cells	32240	**116**	32240	<48

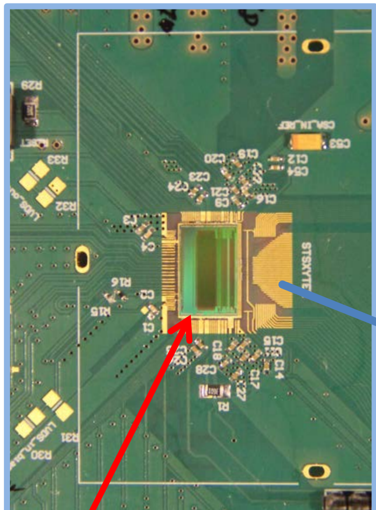
Expectations for STS-XYTER v2 tests

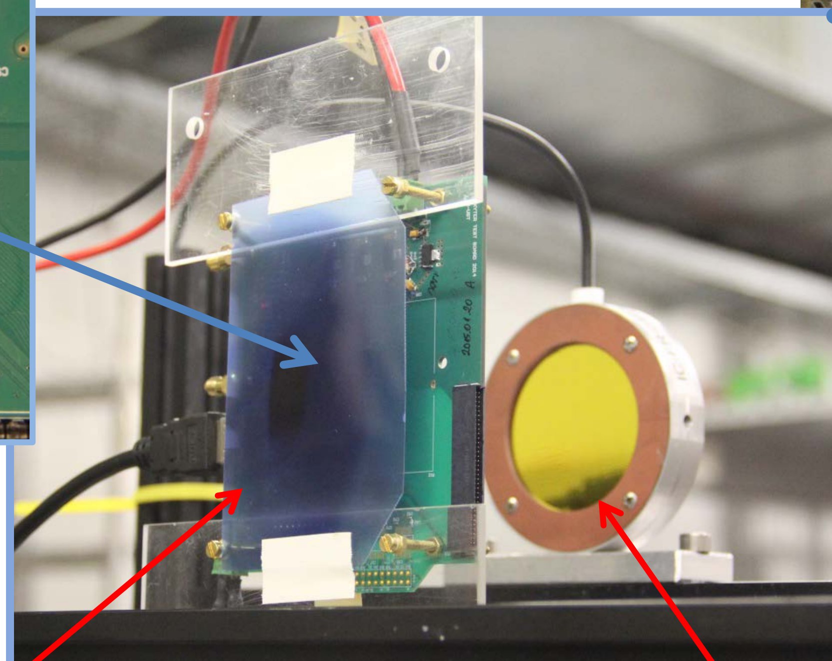
- better SEE statistics for regular flip flops
  - number increased by factor 1.75
- SEE in DICE cells reduced by factor larger than 2
  - improved cell layout (all DICE register bits)

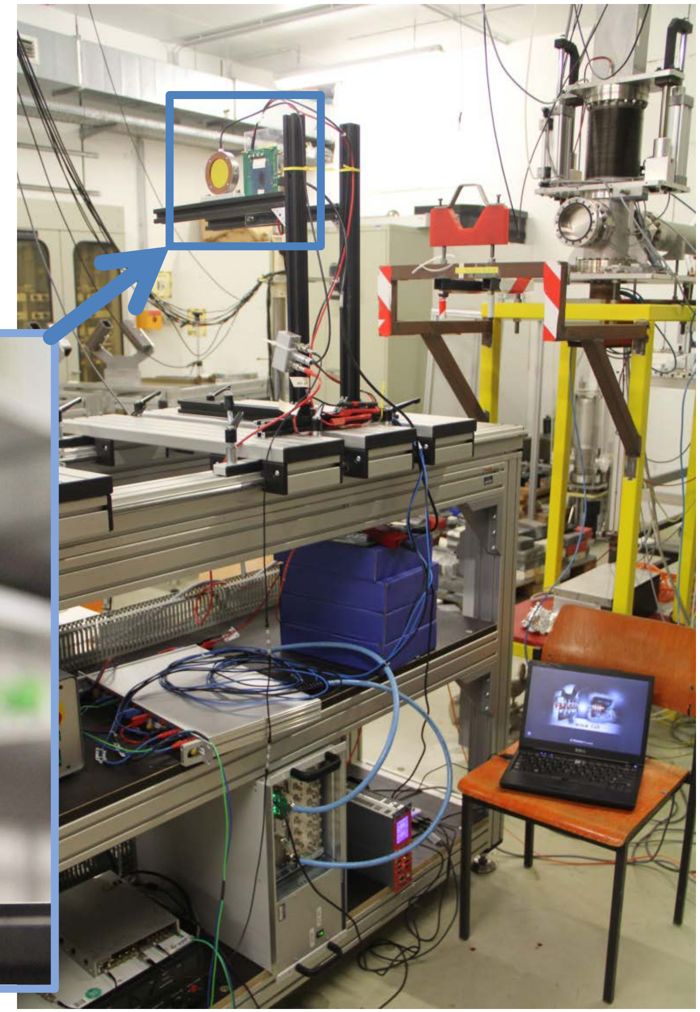


Setup will be similar to the one used in Fall 2015

08.-12.09.2015
FZ Jülich, COSY, JESSICA cave
~3×10^9 p/spill on setup







STS-XYTER ASIC
bonded to FEB

FEB with STS-XYTER v1

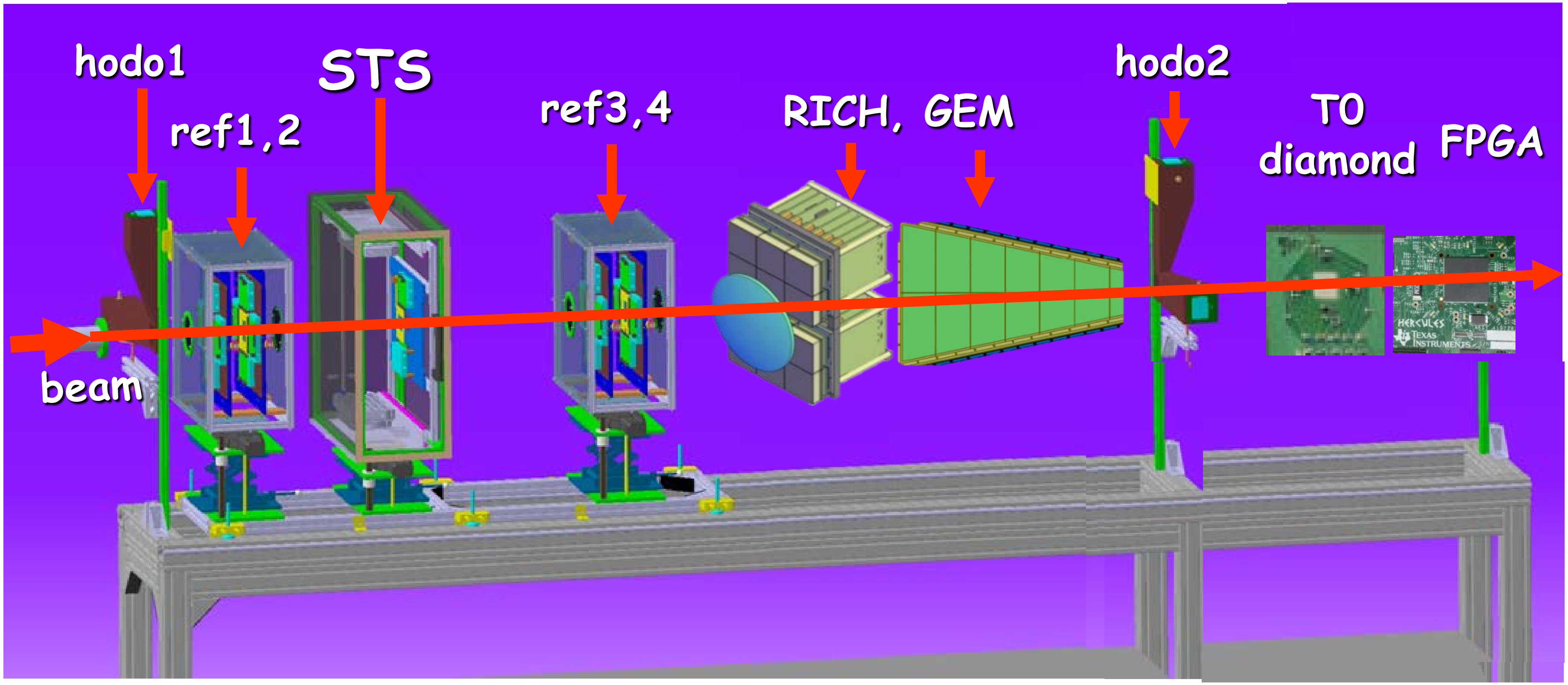
Ionization Chamber with QFW based readout

Beamtime application for electronics test

Total number of particles and type of beam (p,d,polarization)	Momentum range (MeV/c)	Intensity or internal reaction rate (particles per second) minimum needed	maximum useful
p, not polarized	p ~ 1700 MeV/c	10^8/s	10^9/s

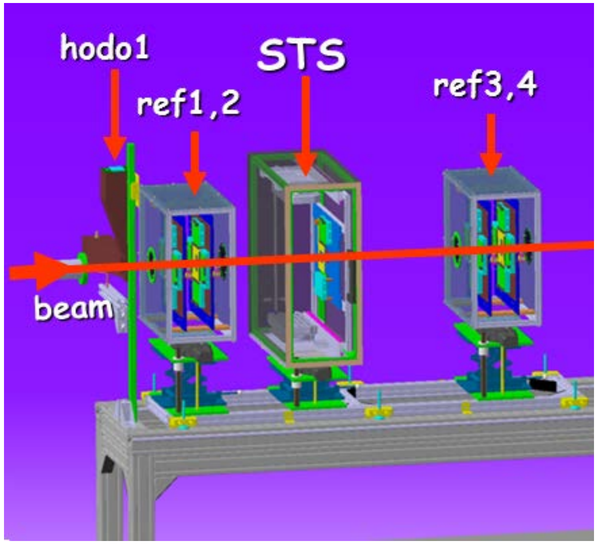
Experimental area	Safety aspects (if any)	Earliest date of Installation	Total beam time (No.of shifts)
JESSICA Cave	none	**week 6, 2/2017** **focus:** STS XYTER v2 SEU tests **optional:** FPGA SEU tests, power regulator TID tests	one week, 24/7

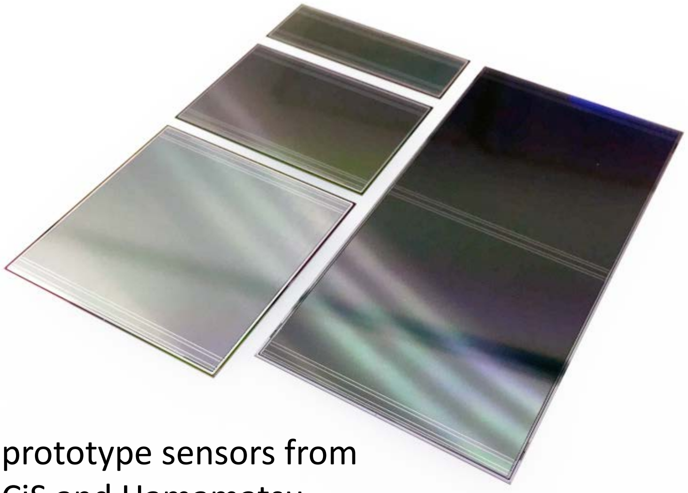
II. Tests of detectors



- 3 large set-ups (STS, RICH, GEM)
- + two smaller ones (T0, FPGA)
- new FEE and DAQ (n-XYTER ASIC based, AFCK-FLIB/FLES)

(a) Tracking efficiency test of STS sensors

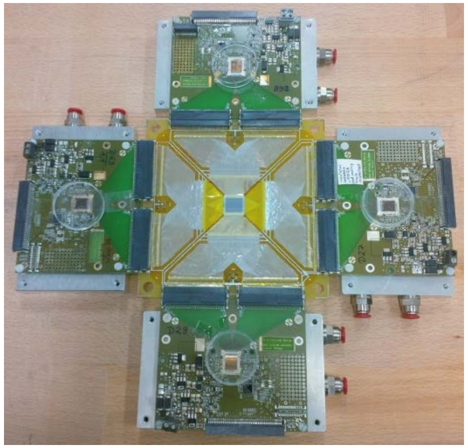




prototype sensors from CiS and Hamamatsu

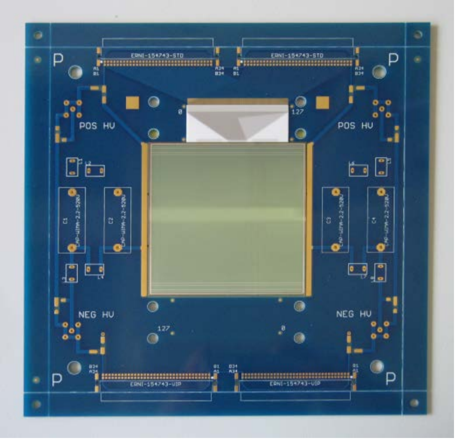
- Aim: Sensor efficiency study with reference tracks. Important to PRR in 2017.
- Sensors irradiated up to CBM life-time fluence (10^{14} n/cm^2) at KIT.
- Operation at below -5 °C **New thermal box under preparation.**

sensor boards



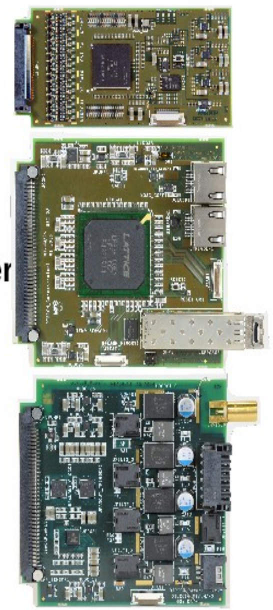
reference stations under constructionn based on n-XYTER FEBs

(electronics/DAQ available to STS from Jan. 2017)

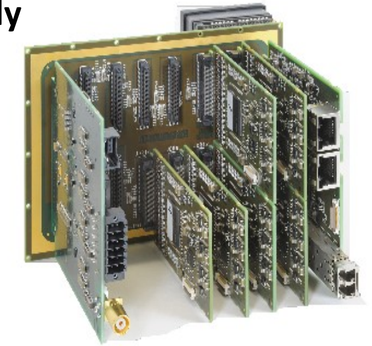


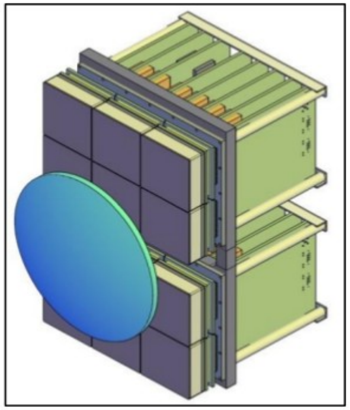
(b) Test of readout electronics for RICH-MAPMTs

- Measure first Cherenkov photons with new DIRICH scheme; study rate behavior
- First steps towards integration of DiRICH chain into CBM DAQ system

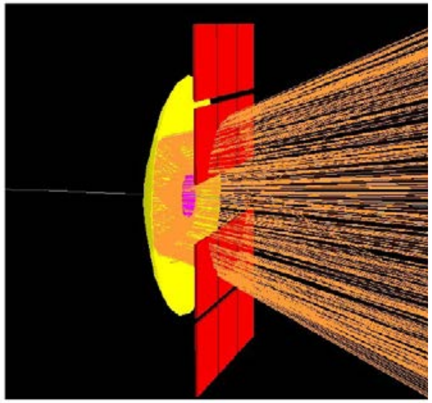


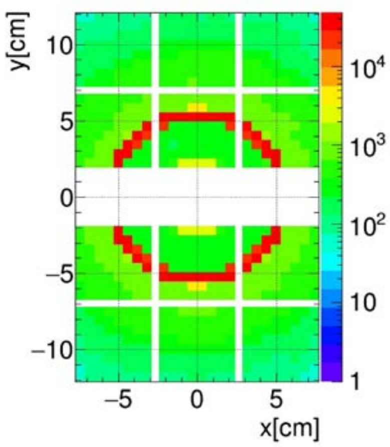
Electronics: ready





- radiator lens with Aluminum coating
- 2x 3x2 PMT matrix
- HADES RICH700 modules



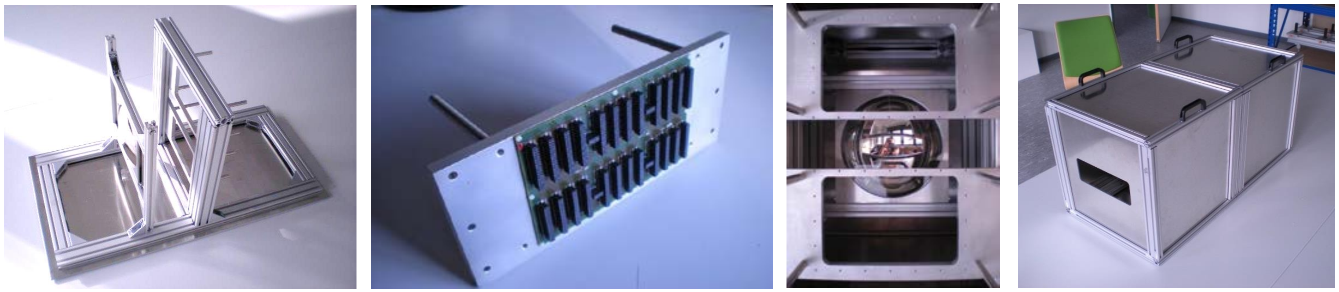


Simulation of ring image on PMT plane at COSY:

beam: p = 1.7 GeV/c, 10^5 protons/s, $\sigma_{x,y}$ = 0.3 cm

- up to $4 \cdot 10^4$ hits/pixel/s
- ~ 20 hits/ring, ring radius: 5.4 cm

Set-up under construction



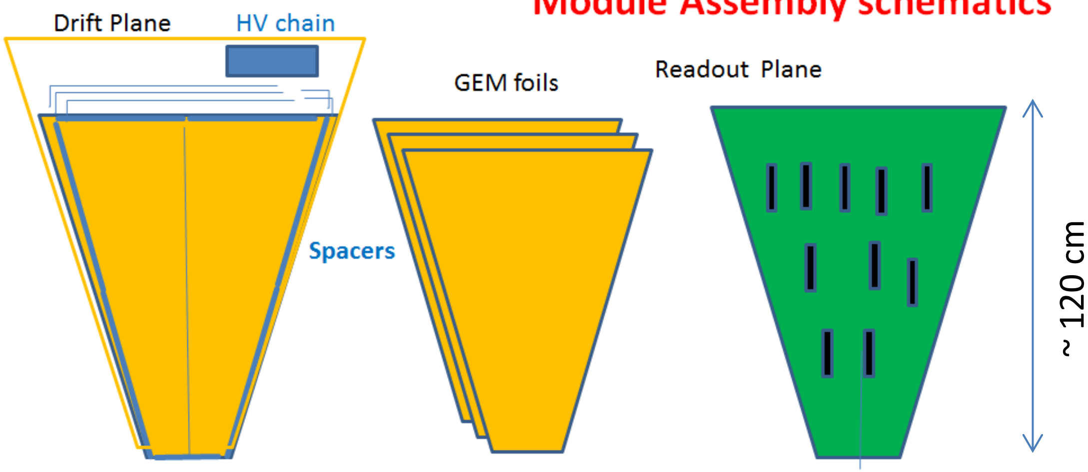
(c) Test of new GEM detectors for MuCH

Two prototypes will be tested:

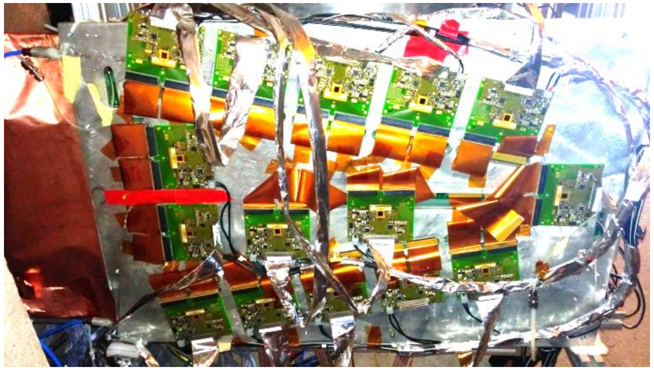
1) *Full-size prototype "M2"*
- *CERN-made GEM foils*
- ***with new HV configuration, possibly involving opto-coupler switches***
- *with full-fledged controlled cooling*
- *with full 18 FEB –F read-out*
- *and latest DAQ*

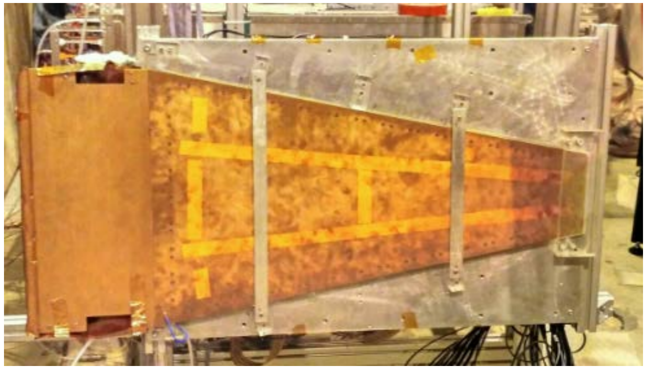
2) Triple-GEM test detector
- *Indian-made GEM foils*
- *10 cm x 10 cm and/or*
- *30 cm x 30 cm*

Module Assembly schematics



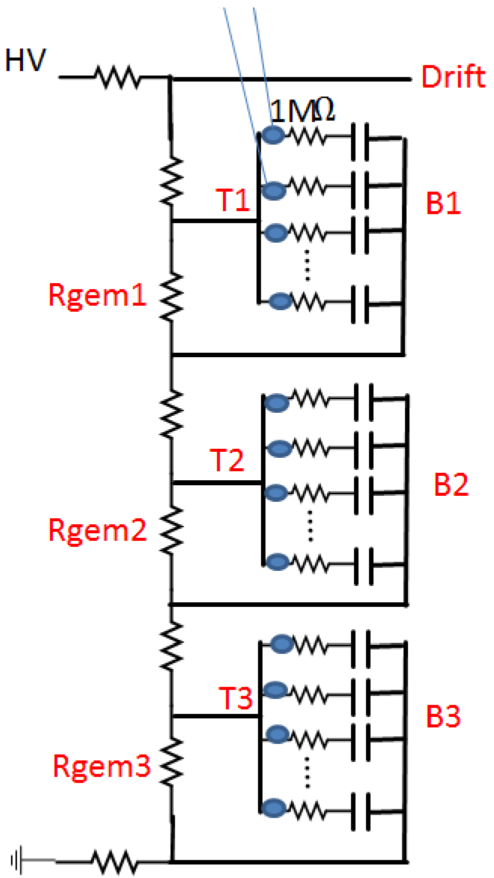
Prototype M1 under test at CERN-SPS, 12/2016



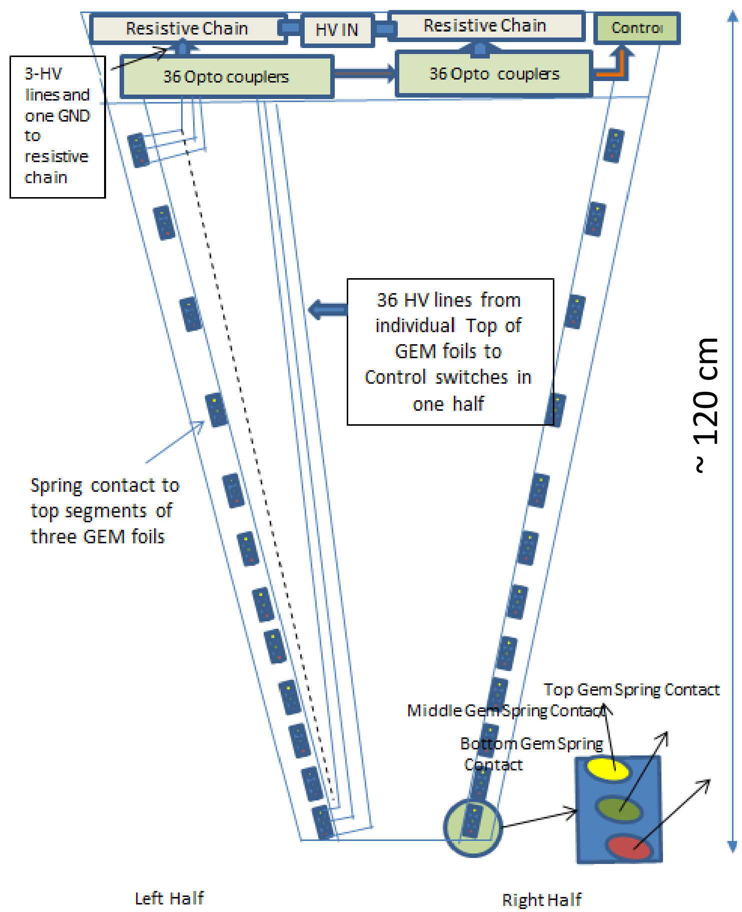


GEM – prototype M2 under construction

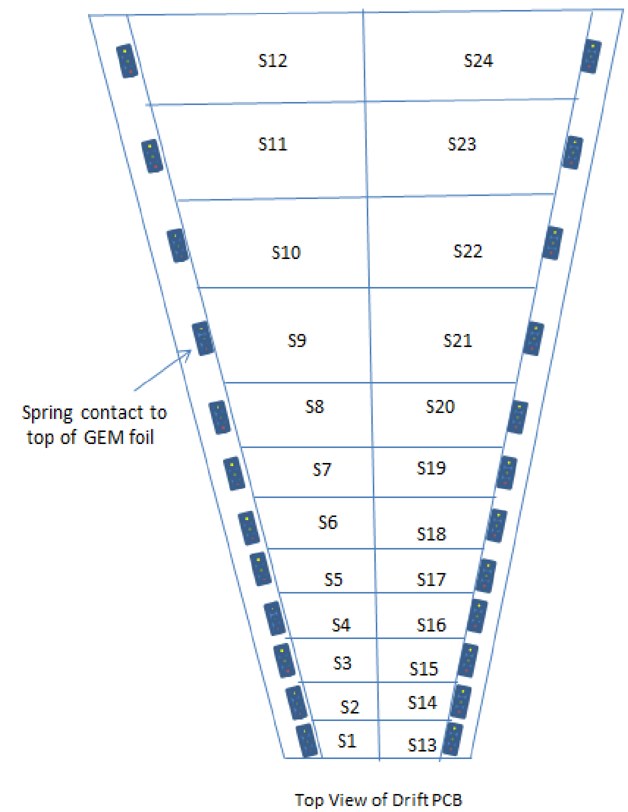
Opto-coupler switches



Bottom of Drift PCB



HV-Layout scheme

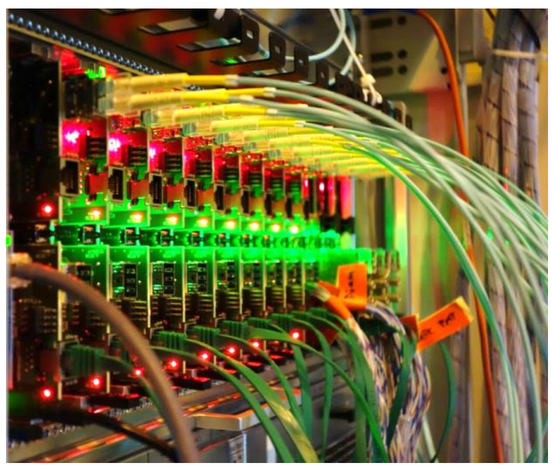


biasing network laid out for high stability under pulsed current

(d) New DAQ system for STS + GEM read-out

Ready: DAQ running at CBM Pb-beamtime (TOF, TRD, GEM), CERN-SPS, 12/2016.
Will be used for STS, Hodoscope + GEM read-out at COSY.

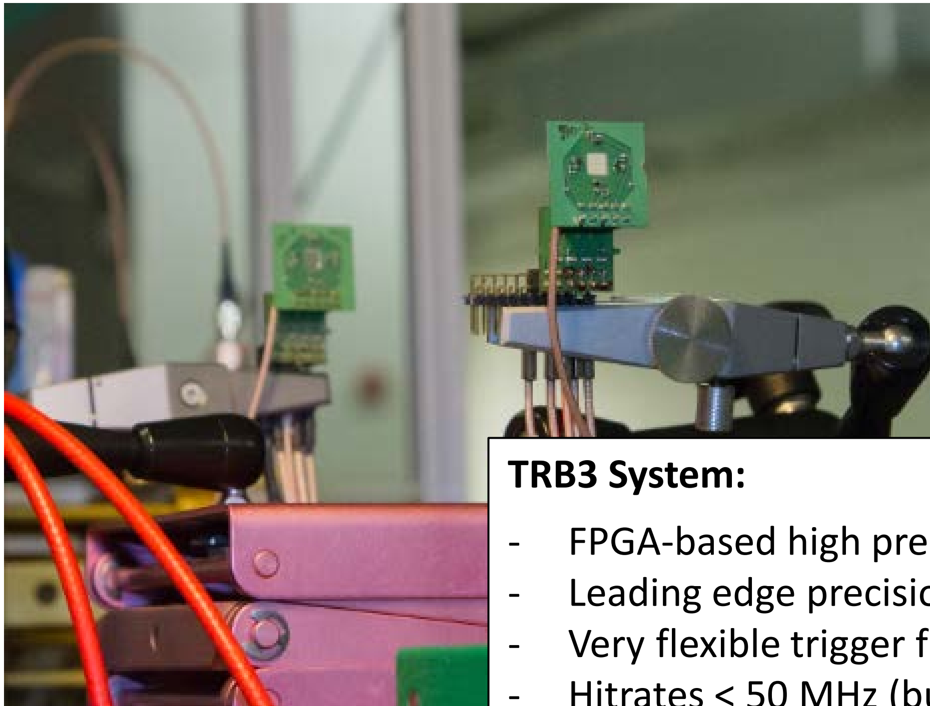
on detector	*on/near detector*	*in* µTCA crates	mFLES
 *n-XYTER FEBs*	 *nDPB*	*nDPB/MUCH* *gDPB* *tDPB*	PCs with FLIBs for time-slice building from the incoming data stream

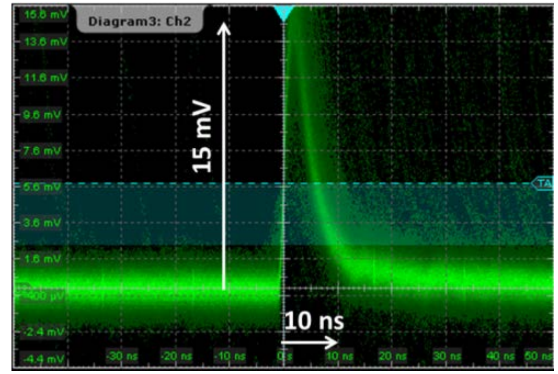


µTCA crates

mFLES

(e) Diamond T0 tests with TRB3 read-out





TRB3 System:

- FPGA-based high precision TDC measurement and DAQ in one
- Leading edge precision: 8-12ps (RMS)
- Very flexible trigger functionality (FPGA)
- Hitrates < 50 MHz (burst)

Used in many FAIR Projects:

- HADES (diamond/trigger/RICH/ECAL),
- CBM RICH,
- PANDA (Barrel-DIRC/Straw)
- and also outside of FAIR: MUSE, A1, ...

Beamtime application for detector tests

Total number of particles and type of beam (p,d,polarization)	Momentum range (MeV/c)	Intensity or internal reaction rate (particles per second) minimum needed	maximum useful
p, not polarized	p ~ 1700 MeV/c	10^4/s	10^6/s

Experimental area	Safety aspects (if any)	Earliest date of Installation	Total beam time (No.of shifts)
Big Karl Cave + two "control rooms" for the large detector groups (GSI, Univ. Frankfurt, TU Darmstadt, Univ. Giessen Univ. Wuppertal, VECC Koktata): room at Big Karl, and Wasaquarium	none	**weeks 19+20, 5/2017** * STS with DCS, DAQ, Online Analysis; * GEM prototypes; * RICH + DAQ; * diamond T0 detector.	two weeks, 24/7

The two CBM beamtimes summarized

Total number of particles and type of beam (p,d,polarization)	Momentum range (MeV/c)	Intensity or internal reaction rate (particles per second) minimum needed	maximum useful
p, not polarized	p ~ 1700 MeV/c	10^4/s	10^6/s (detectors) 10^9/s (electronics)
Experimental area	**Safety aspects (if any)**	**Earliest date of Installation**	**Total beam time (No.of shifts)**
JESSICA Cave	none	**week 6, 2/2017** **focus:** STS XYTER v2 SEU tests **optional:** FPGA SEU tests, power regulator TID tests	one week, 24/7
Big Karl Cave + two "control rooms" for the detector groups: room at Big Karl, and Wasaquarium	none	**weeks 19+20, 5/2017** * STS with DCS, DAQ, Online Analysis; * GEM prototypes; * RICH + DAQ; * diamond T0 detector	two weeks, 24/7

Appendix

slide from CBAC Meeting #2

SEE Tests

- Goal: first qualification of STS-XYTER DICE cell architecture with respect to Single Event Effects (SEE):
  - quantitative assessment of SEE cross sections for DICE cells and comparison to the regular flip flops in the design
  - dependency of SEE cross sections on incident angle

- Expected SEE cross sections in the order of 10^{-13} to 10^{-14} cm^2/bit for regular flip-flops and 10^{-14} to 10^{-15} cm^2/bit for DICE cells
  - DICE cross section may be significantly increased in case of inadequate cell architecture
  - Depending on DICE architecture inclined incidence may increase cross section

- Tests
  - Count SEEs (readback of STS-XYTER registers)
  - Measure at perpendicular incidence: 90 (compatible with literature values)
  - Measure at inclined incidence: >≈ 25°
    typical incidence angle for ASIC installation in CBM-STS

SEE Rate Estimate for STS-XYTER v2

- Compare
  - DICE cells: **32240 bits** (Trim DACs settings) – same number as with STS-XYTER v1
    → test with any predefined bit pattern
  - Regular flip flops: **56420 bits** (ADC discriminator counters → 14bit instead of 8bit in STS-XYTER v1)
    → test with random bit pattern

- 1 week in JESSICA cave: *compared to Sep. 2015*
  - More DUTs
    - 2 ASICs with perpendicular incidence
      (approx. compensates for lower expected SEE rate for DICE cells)
    - 1 ASIC with ~25 degree incidence as in CBM-STS
      - Check for variations in SEE rate depending on incidence angle
  - Longer effective duration of irradiation (more robust and recoverable readout interface)
  - Higher beam intensity