Vertex 2008 - *17th International Workshop on Vertex Detectors*
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ATLAS Diamond
Beam Conditions Monitor

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on behalf of Irena Dolenc and
ATLAS BCM collaboration

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BCM web page: https://twiki/cern.ch/twiki/bin/view/Atlas/BcmWiki

Motivation

The goal of BCM system inside the ATLAS Inner Detector:

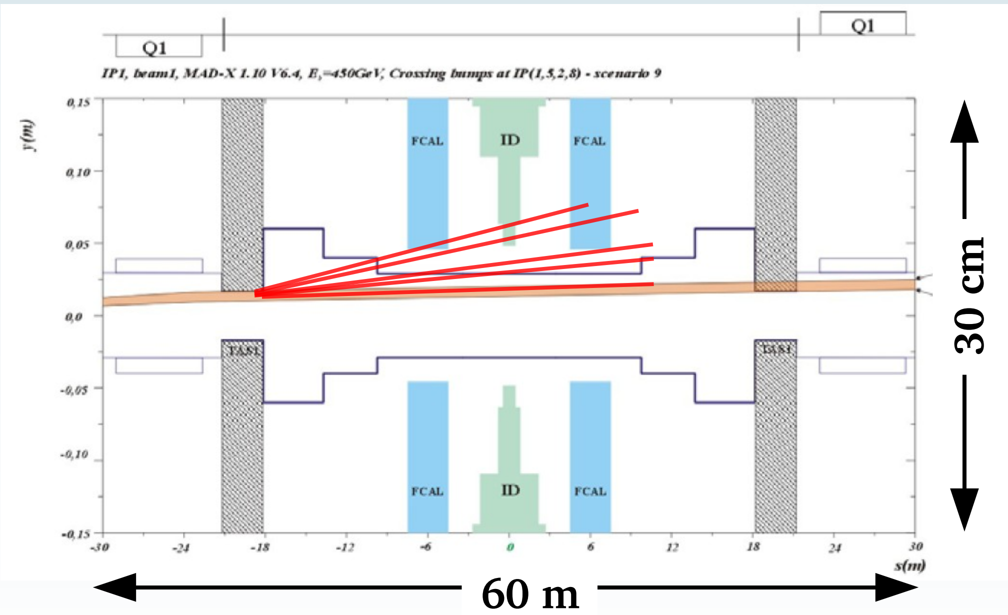
- Monitor beam conditions and distinguish each bunch crossing between normal collisions and background events during normal running
  - measure background rate (beam halo, beam gas) close to the vertex
  - measure collision rate and provide (bunch by bunch) relative luminosity information (additional measurement to LUCID, ATLAS main luminosity monitor)
  - simulation in full ATHENA framework: average number of tracks in all BCM modules per p-p collision = 0.375

- Primary goal: **protection** in case of larger beam losses
  - fast detection of early signs of beam instabilities (due to incorrect magnet settings, trips, ...)
  - Issue warning and alarm signals for equipment protection
  - Input to ATLAS Detector Safety System and LHC Beam Abort

Beam Loss Scenarios

- Multi-turn losses
  - beam degradation due to magnet failure or wrong change of settings, collimator failure etc.
  - time constants of magnets ~ms → can abort the beam if detected early

- Single-turn losses of 360MJ/beam
  - likely to occur during
    - injection (unsynchronised kicker fire, wrong magnet settings in transfer line)
    - beam dump (kicker pre-fire), but beam dump collimators and absorbers are expected to handle the problem
  - IR1 (ATLAS) can be rated the 'safest' of all interaction points (far away from injection, dump)
  - local damage at injection due to wrong magnet settings in IR1
  - pilot bunch (single bunch of low intensity, 5×10^9p@450GeV; 360J) will be used to check the magnet settings
  - simulations of beam orbits with wrong magnet settings (D. Bocian) exhibit scenarios with beam scrapping TAS Cu collimator



- Most likely scenario:

  pilot bunch scraping the TAS
  - "no sizeable permanent damage to the ATLAS pixel detector" (NIMA 565, (2006), p50-54)

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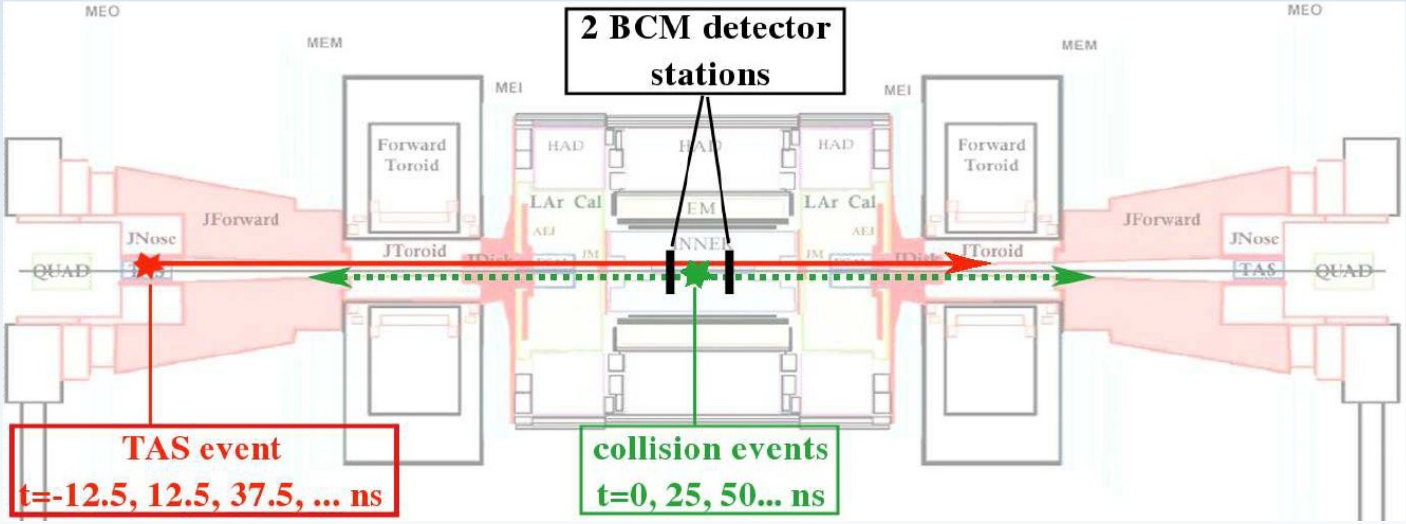
  - IR1 (ATLAS) can be rated the 'safest' of all interaction points (far away from injection, dump)
  - local damage at injection (wrong magnet settings in IR1)
  - can occur during beam dump process (kicker malfunction), beam dump collimators and absorbers are expected to handle the problem
  - likely to occur at injection (wrong magnet settings in IR1)
  - IR1 (ATLAS) can be rated the 'safest' of all interaction points (far away from injection, dump)
  -

ATLAS BCM principle of operation

Time of flight measurement to distinguish between collisions and background events (beam gas, halo, TAS scarping… occurring downstream)

- measurement every proton bunch crossing (25 ns)
- place 2 detector stations symmetrically on either side of interaction point at $z=\pm 1.9$m:
  - secondary particles from **collisions** reach both stations at the same time (6 ns after collisions)
  - secondary particles from upstream **background** interactions reach nearest station 12.5ns before secondary particles from collisions (6 ns before collisions)
  - use "out of time" hits to identify the background events
  - use "in time" hits to monitor luminosity

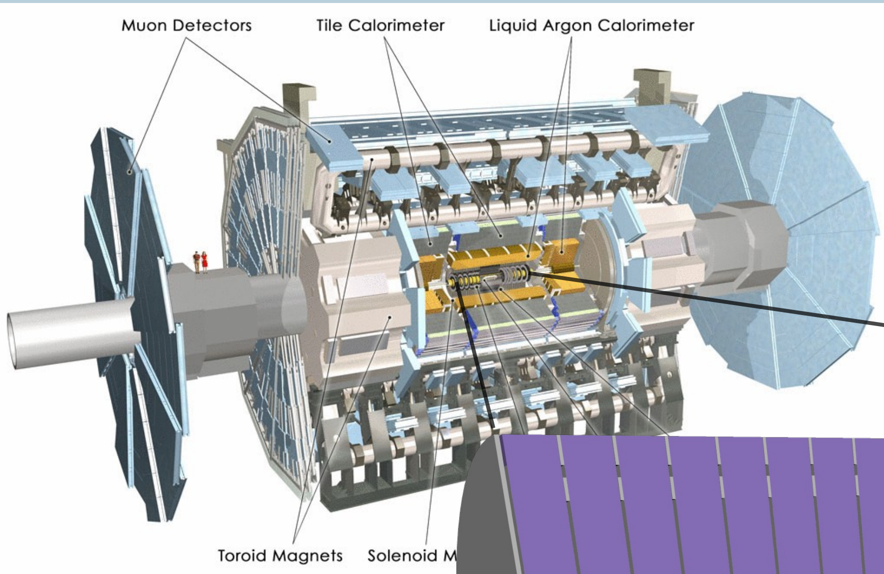


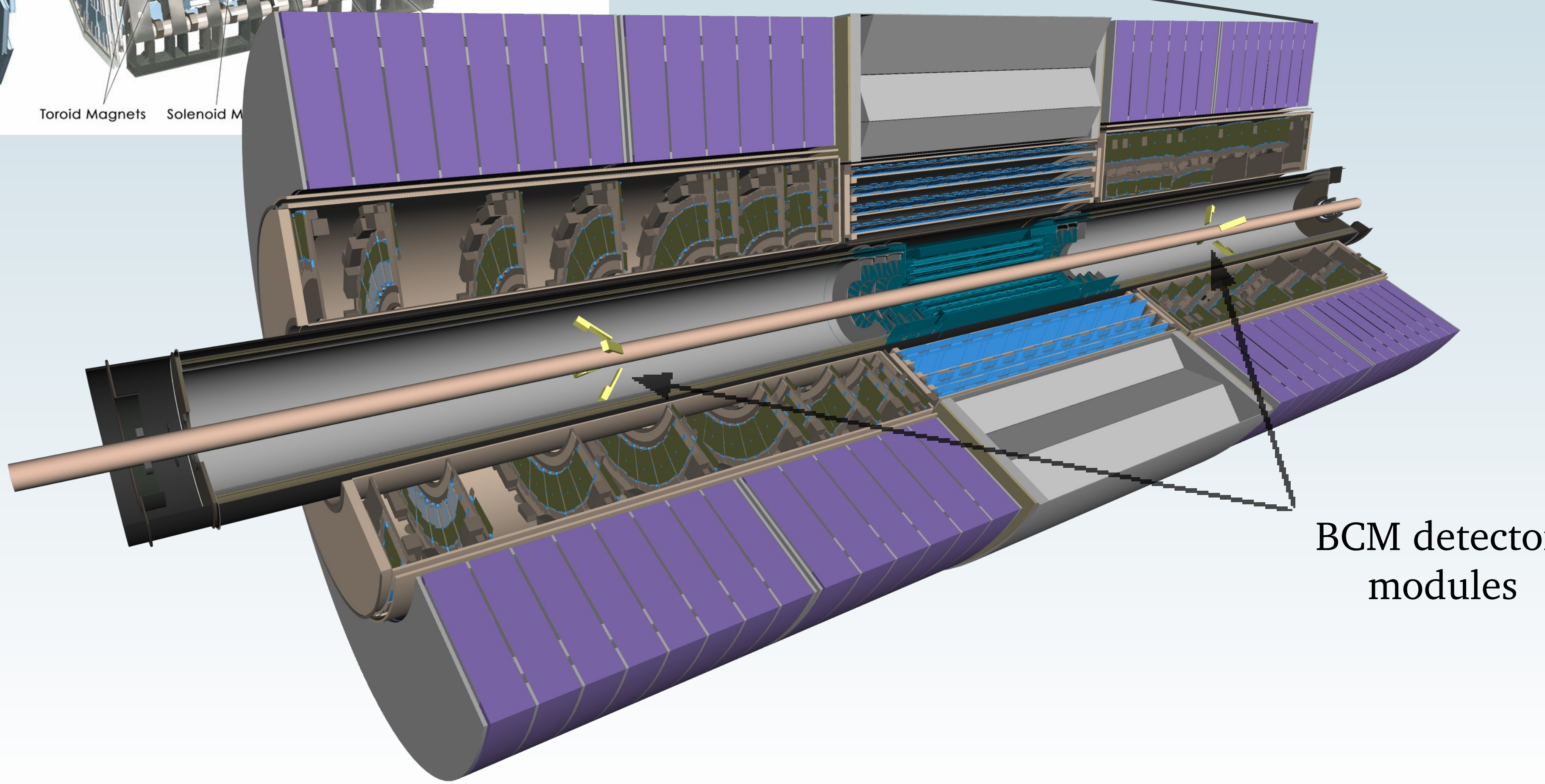
Requirements:

- fast and radiation hard detector & electronics:
  - rise time ~1ns
  - pulse width ~3ns
  - baseline restoration ~10ns
  - ionization dose ~0.5 MGy, 10^{15}particles/cm^2 in 10 years
- MIP sensitivity

Realization

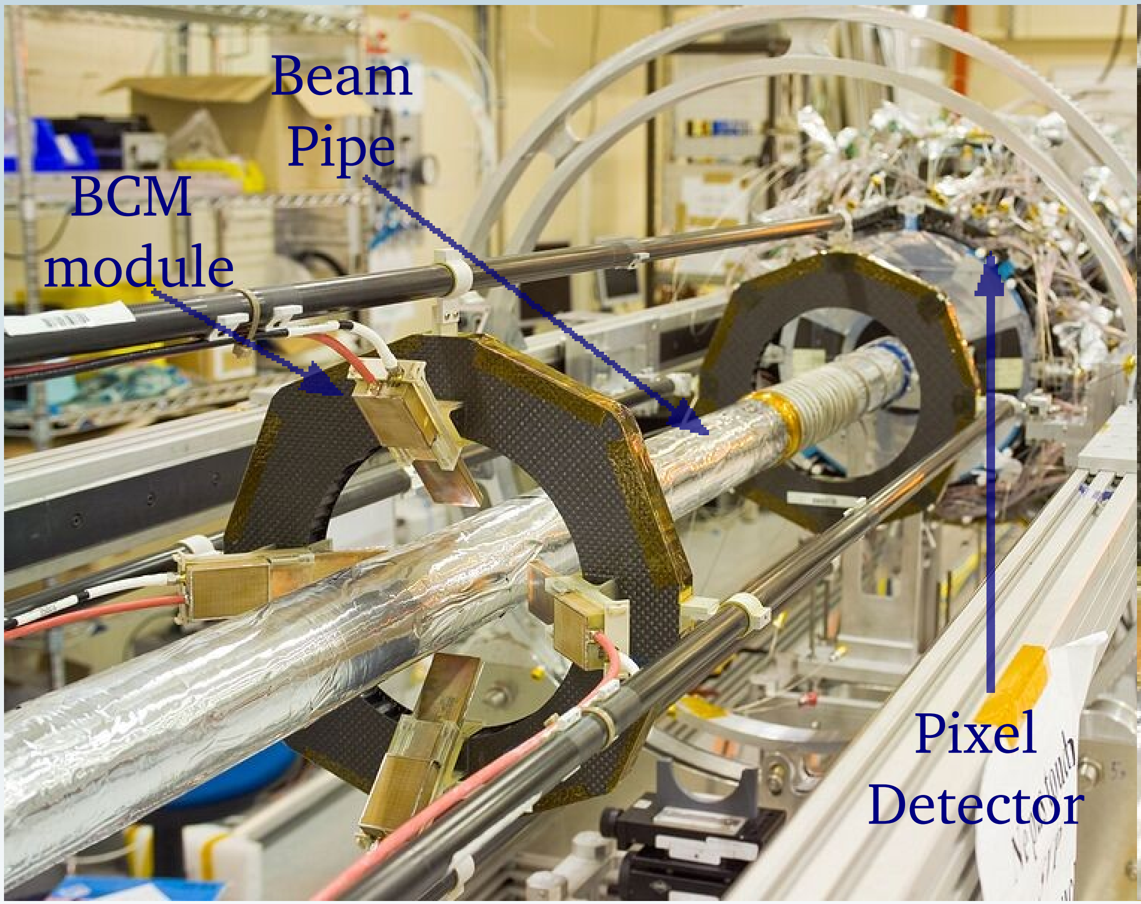
- 4 BCM detector modules on each side of the Pixel detector
- Mounted on Beam Pipe Support Structure at $z=\pm183.8$cm, sensors at $r=5.5$cm ($\eta\approx4.2$)

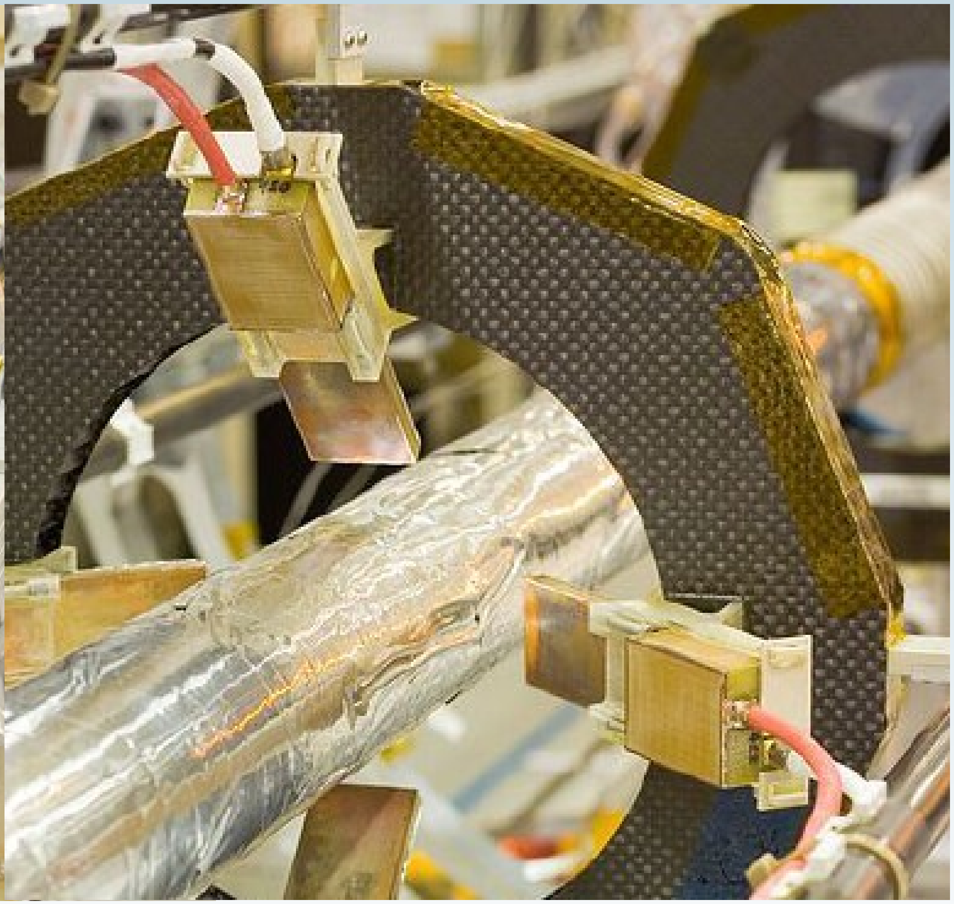




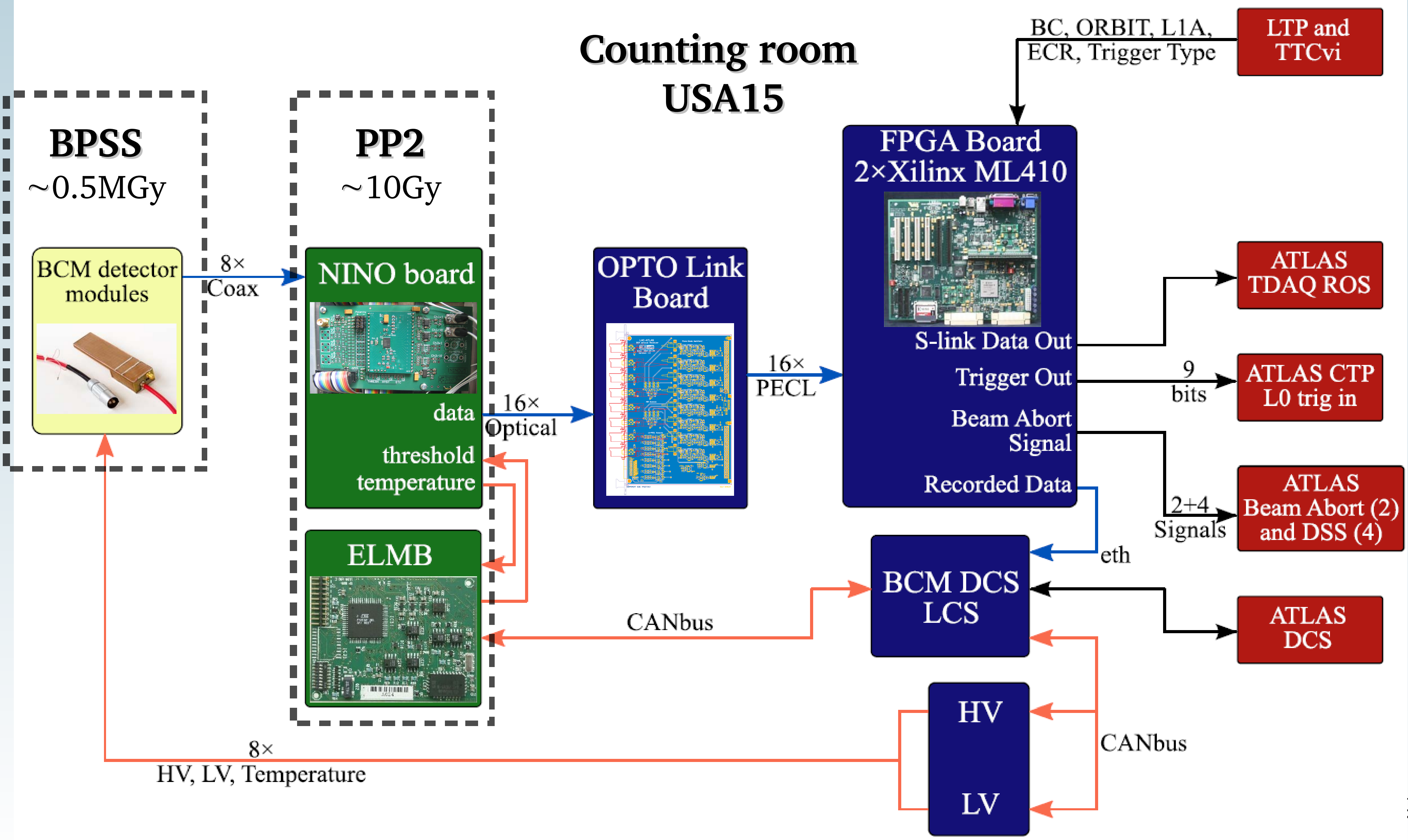
BCM Detector Modules Installed

BCM modules were installed on Beam Pipe Support Structure in Novemeber 2006 and lowered into ATLAS pit in June 2007





BCM System - Schematics



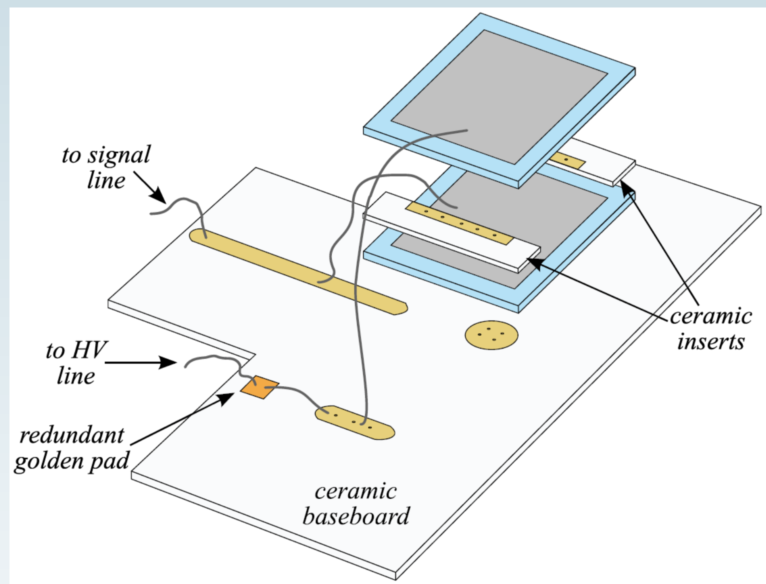
BCM Detector modules

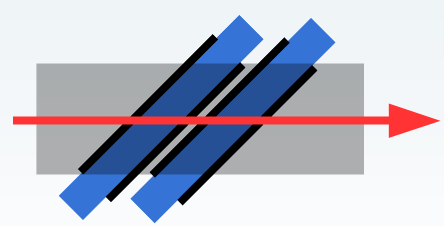
Poly-crystalline CVD diamond sensors

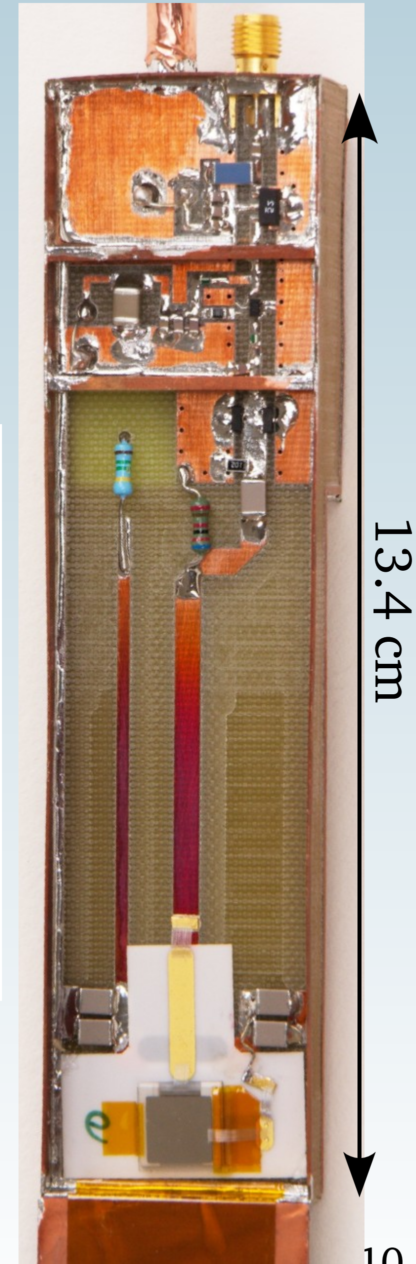
- developed by RD42 and Element Six Ltd.
- radiation hard: shown to withstand 10^{15}p/cm^2
- low leakage current → no cooling required
- fast & short signals
  - operates at high drift field 2V/µm → high charge carrier drift velocity (10^7cm/s)

Double – decker assembly

- 2 back-to-back sensors each with
  - thickness 500µm,
  - CCD @1V/cm ~220µm
  - Size: 10×10 mm^2
  - Contact size: 8×8 mm^2
  - Operated at 2V/µm (1000V)
- double signal compared to assembly with one sensor, but noise not measured to be two times higher
- for 45^o particle incidence signal increase by factor √2 → modules installed at 45^o to the beam pipe



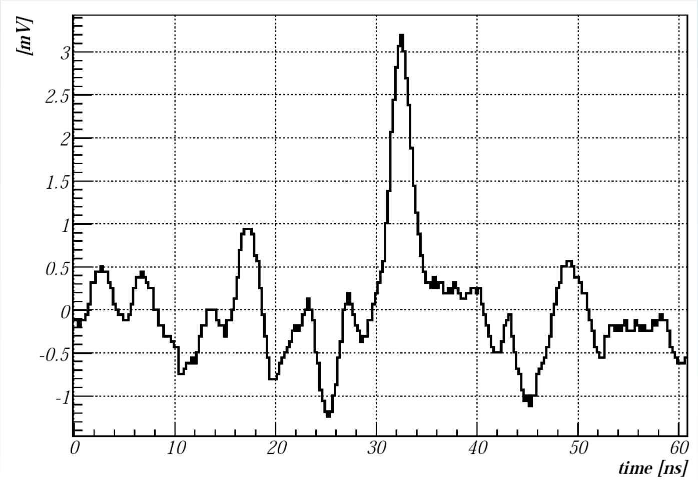


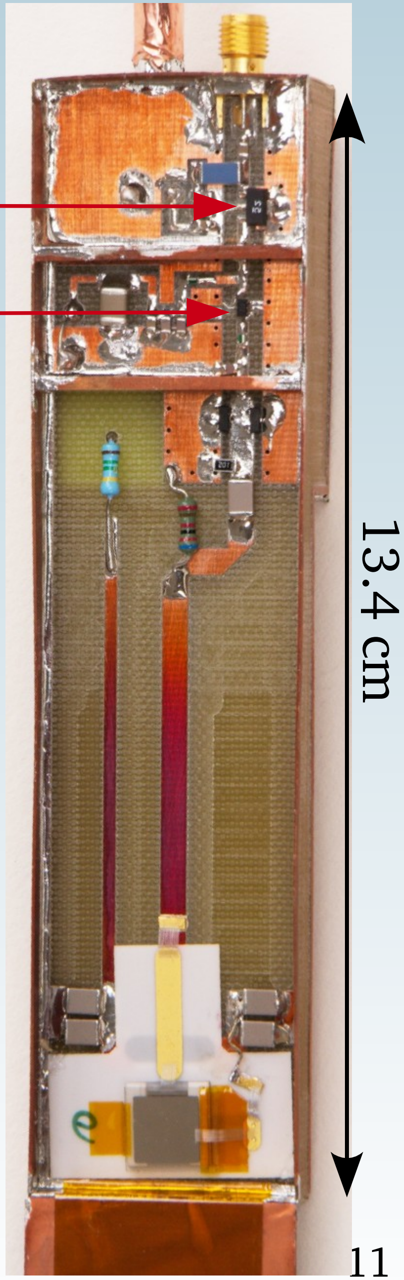


BCM Detector modules

Front end electronics

- **2 stage amplifier:**
  - 1^{st} stage: Agilent MGA-62653, 1GHz (20dB)
  - 2^{st} stage: Mini Circuit GALI-52 500MHz (22dB)
- Limiting BWL to 200MHz improved S/N by 50% (but 10% worse timing resolution)
  → 4^{th} order 200MHz filter integrated on NINO board before digitization
- Signals recorded with LeCroy LC564A digital oscilloscope with 200MHz BWL:
  - mean rise time 1.4ns
  - mean FWHM 2.9ns

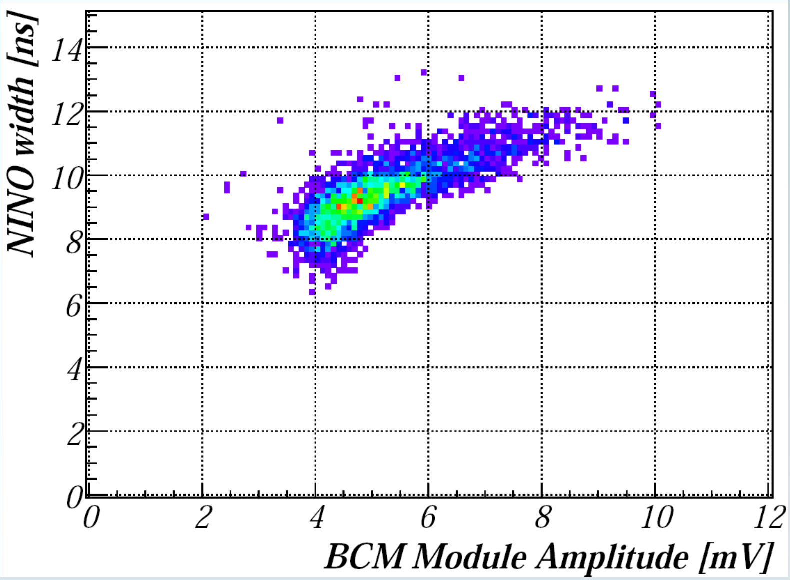


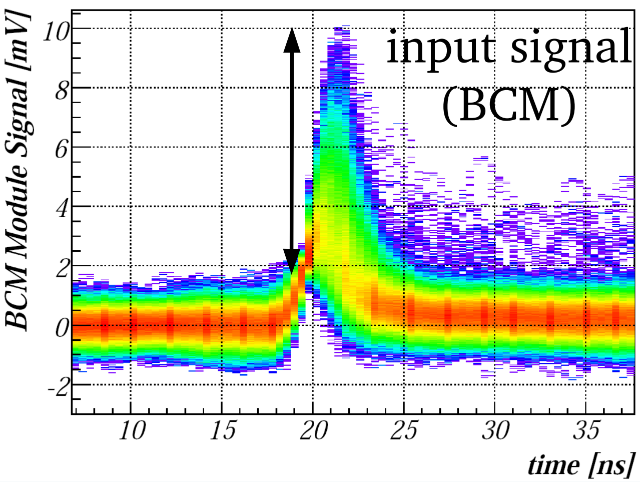


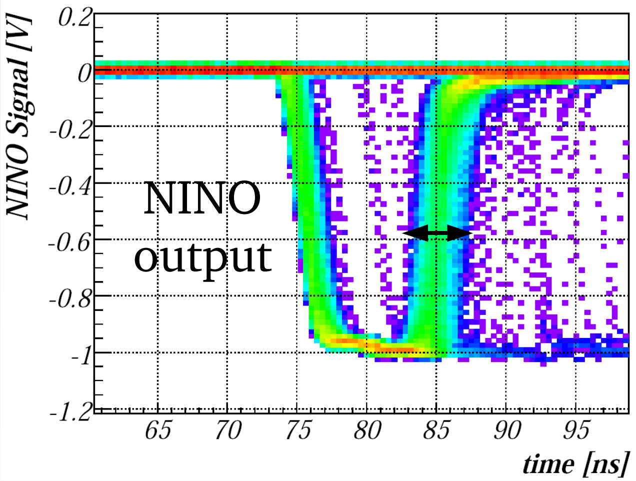
NINO board

NINO chip

- Developed for ALICE ToF (F. Anghinolfi et al.)
- Radiation tolerant
- Fabricated in 0.25µm IBM process
- Peaking time< 1ns, jitter <25ps
- Min. detection threshold 10fC
- Time-over-threshold amplifier-discriminator chip
- width of LVDS output signal depends on input charge



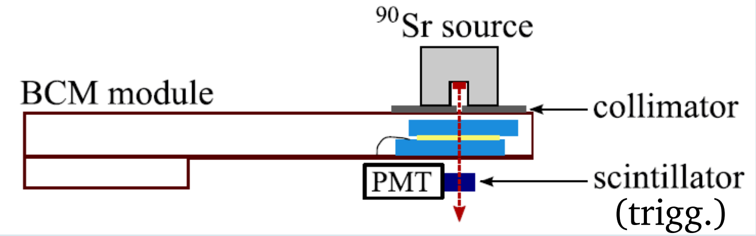


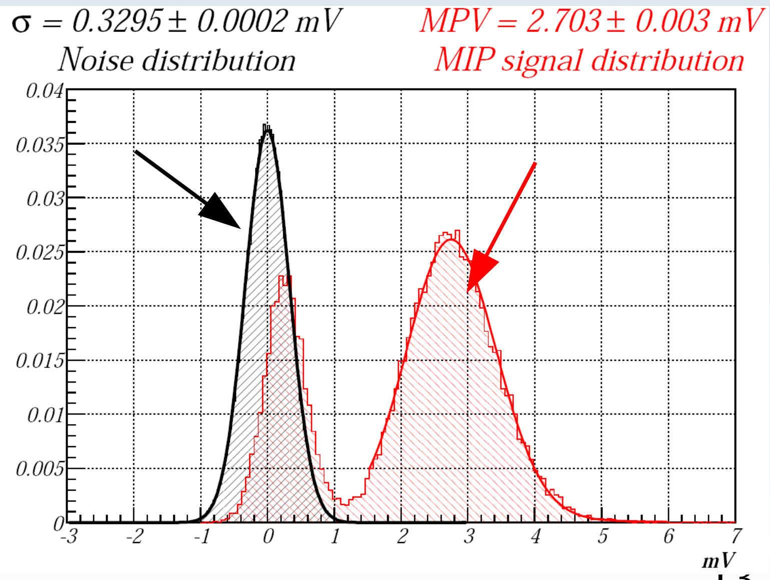


QA of BCM Modules

Qualification tests with final modules to select 8 for installation

- Raw sensor characterization:
  - I/V, CCD
- Module performance
  - All modules subjected to thermo-mechanical test
    - infant mortality test (12h @80°)
    - accelerated ageing for one of the module (14h @120° 10 years at 20°)
    - thermal cycling (10 cycles from -25° to 45°)
  - Module performance checked before and after these tests with ^{90}Sr setup
    - no change in S/N observed
    - for normal particle incidence: typical S/N≈7–7.5



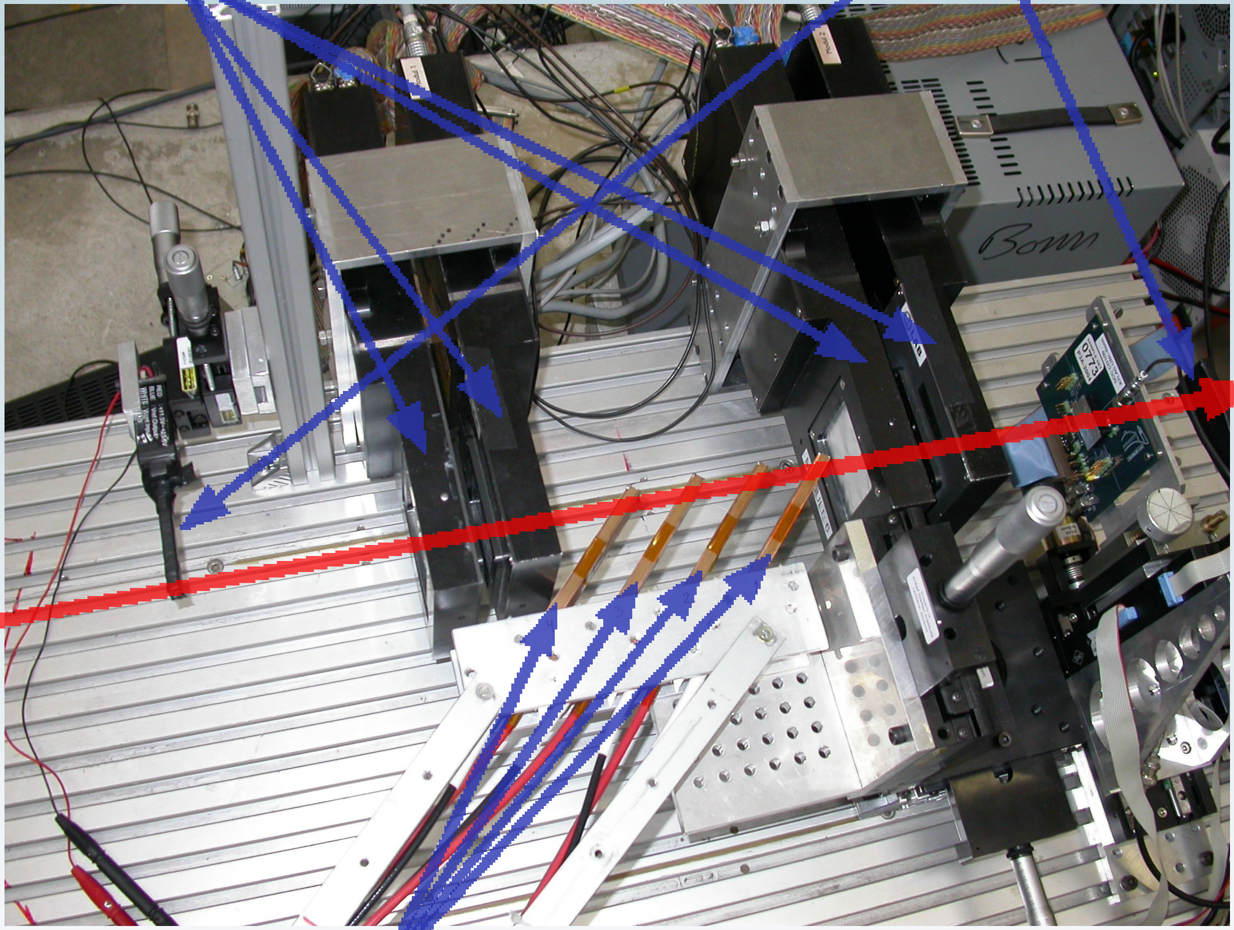


MODULE	404	405	408	410	413	420	422	424
Polarity	+	+	-	+	+	-	-	-
MPV [mV]	2.4	2.3	2.3	2.7	2.2	2.7	2.4	2.7
S/N	6.6	6.9	7.0	7.8	7.0	7.9	7.4	8.2
Current [nA]	70	35	20	25	250	200	40	10

Test Beam at CERN SPS/PS in 2006: Setup

Bonn Telescope:
4 Si-strip tracking modules
(4 XY points along pion path)

Trigger scintillators

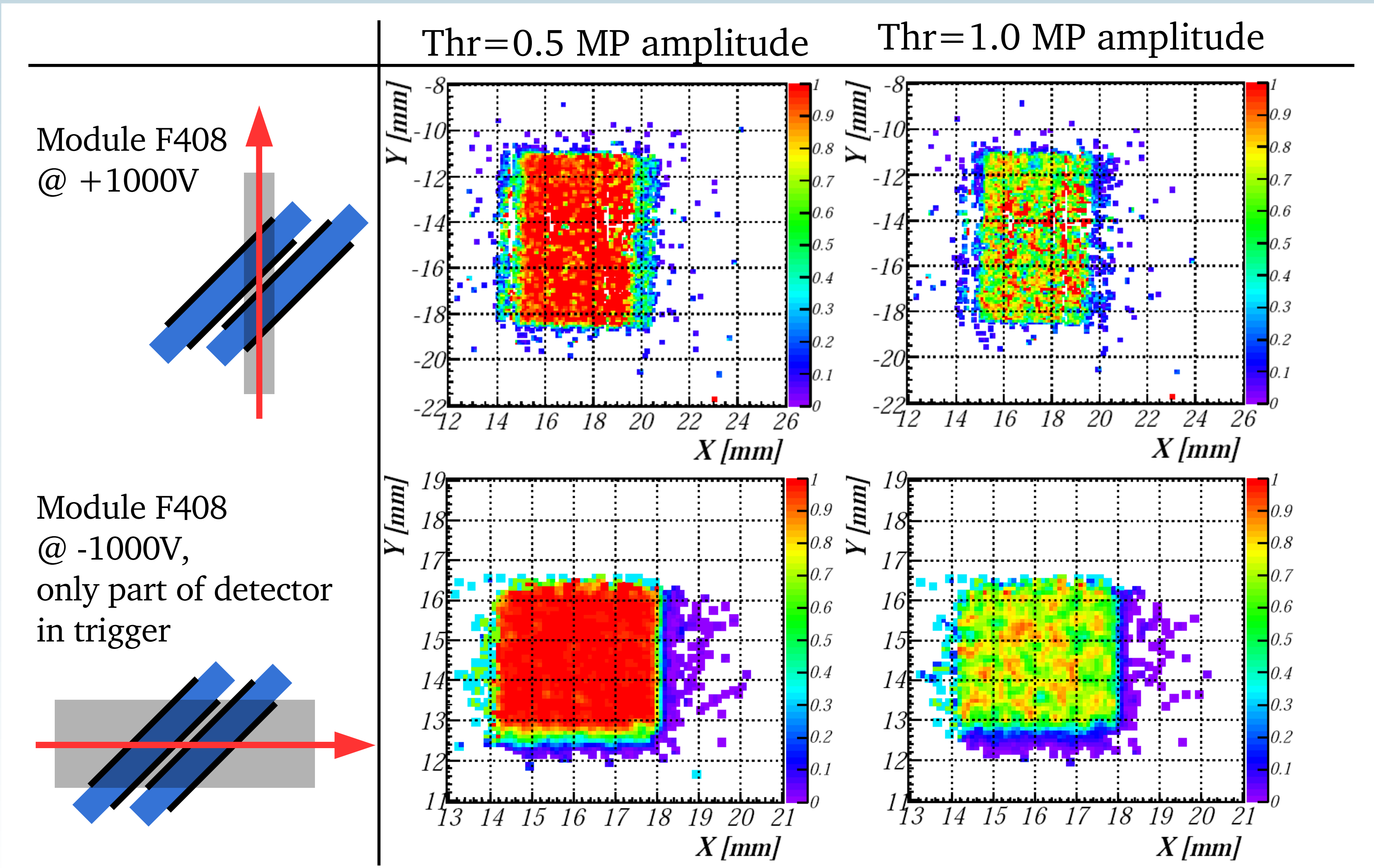


Pion Beam
T9: p=3.5G eV/c
T11: p=12 GeV/c
H8: p=20,100 GeV/c

BCM detector modules

Test Beam at CERN SPS/PS in 2006: *xy* efficiecny scan with analogue signals

Detector response:
moving in steps of 0.1mm across the *xy* surface, calculating the fraction of tracks with analogue signal above chosen threshold in $0.2{\times}0.2\text{mm}^2$ square at each step



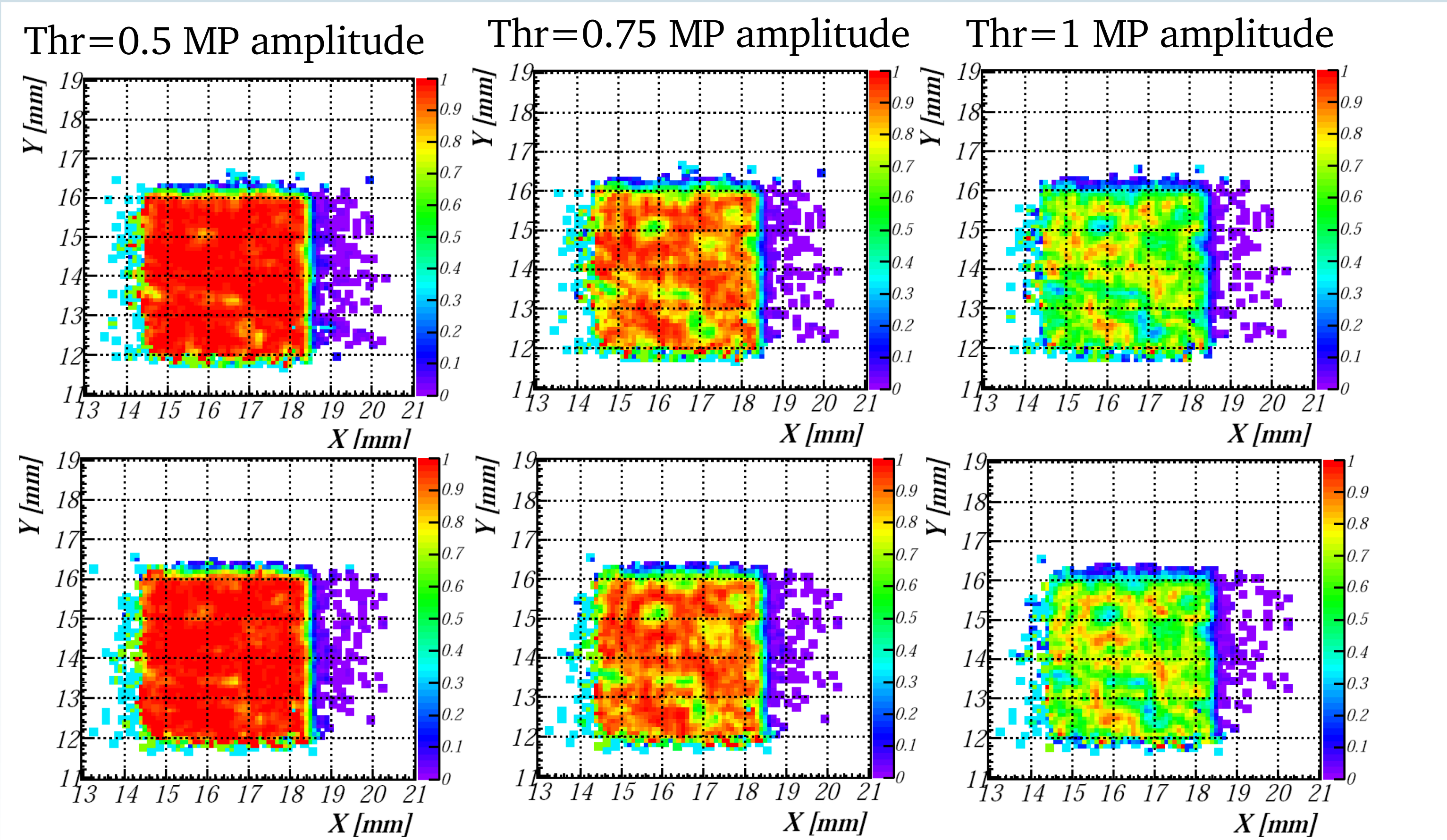
Test Beam at CERN SPS/PS in 2006:
xy efficiecny scan with analogue signals

Moving in steps of 0.1mm across the *xy* surface, calculating the fraction of tracks with analogue signal above chosen threshold in $0.2\times0.2\ \mathrm{mm}^2$ square at each step:

- Longer period of data taking divided in two parts (no mutual events)
- Same pattern observed for both time periods → non-uniformity due to the grain structure of the diamonds in assembly
- example of plots bellow: only part of BCM detector in trigger, mean values of efficiency distributions found in $2\times2\mathrm{mm}^2$ or $3\times3\ \mathrm{mm}^2$ differ up to 10%

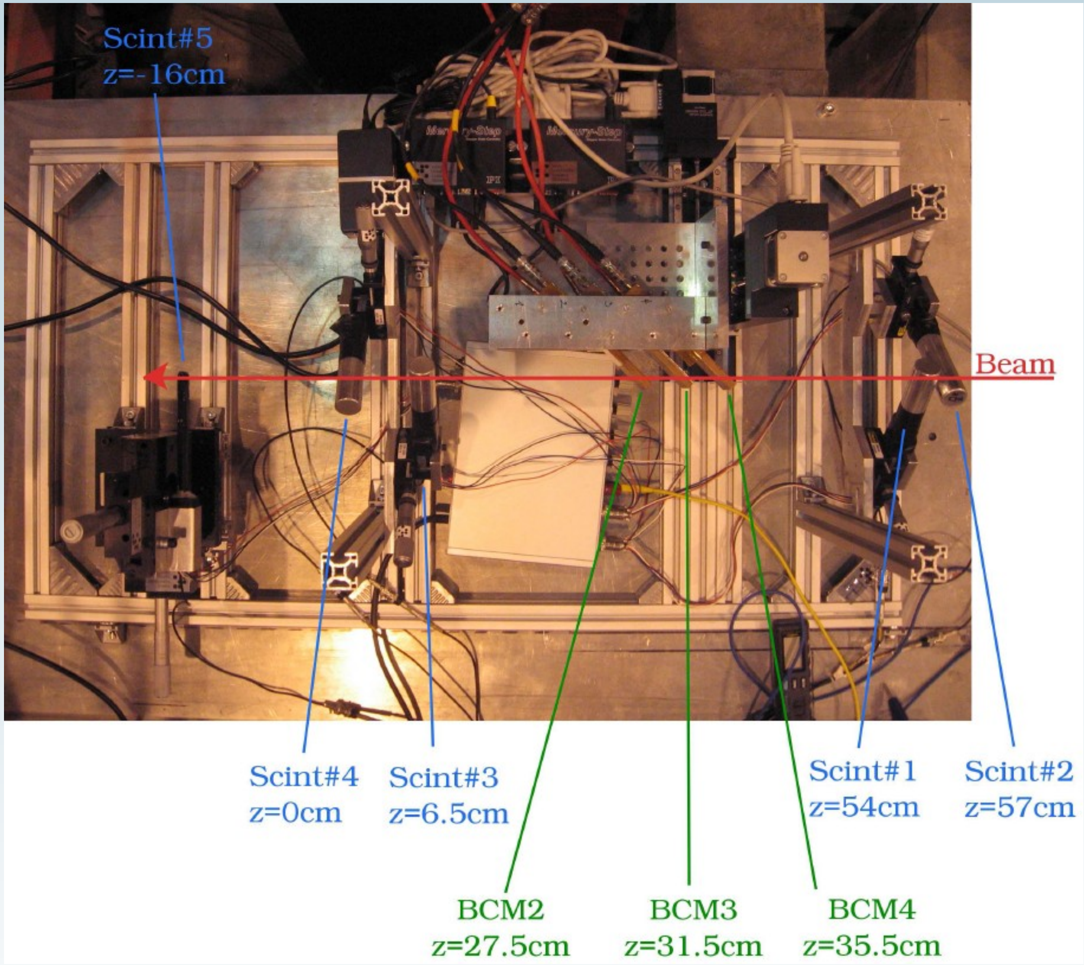
1st period

2nd period



Test Beam at CERN SPS in 2007

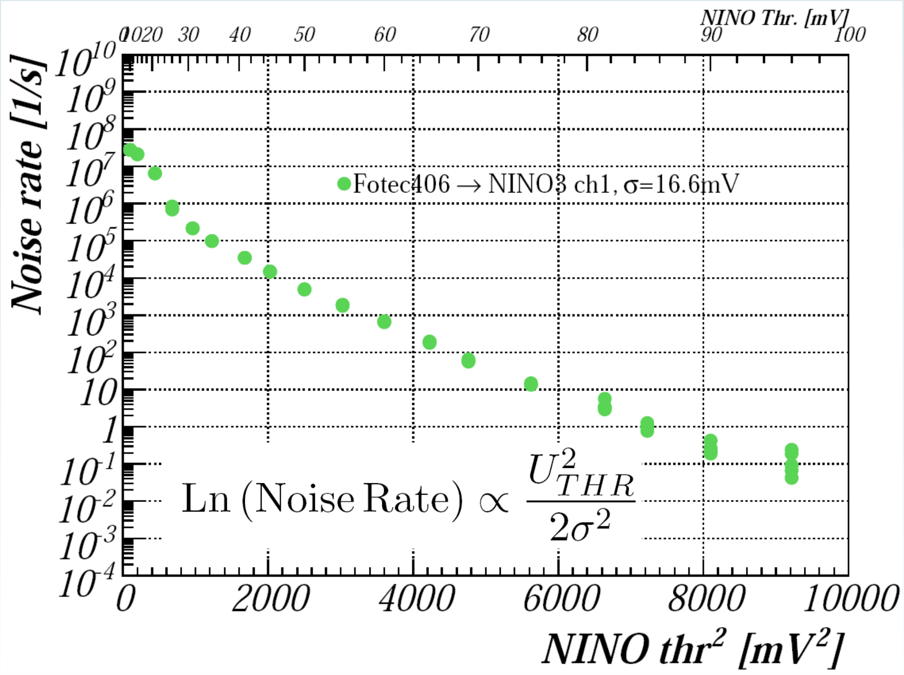
- H6 (p=120GeV/c) and H8 (p=180GeV/c) pion beam
- Signal waveforms recorded with 12-bit ADC (CAEN Va729), 2GHz sampling
- Pion position information
  - 4 thin scintillators ($2\times2mm^2$)
  - Detector modules placed on movable x and y stages, remotely controlled
- Objectives
  - establish the digital performance of NINO board with 3 spare BCM detector modules
  - Test FPGA code

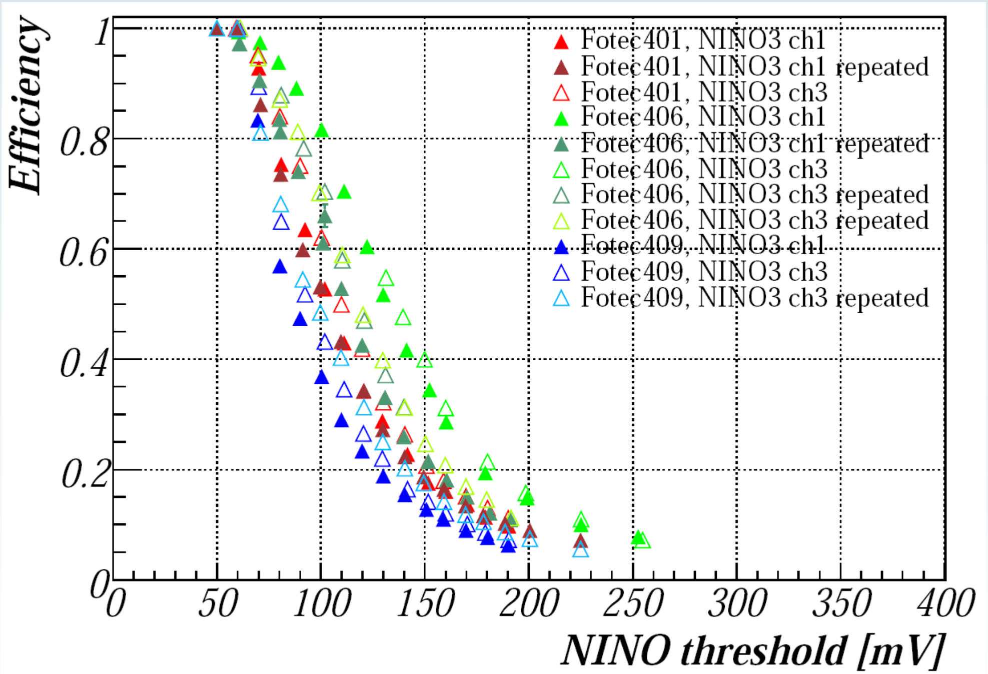


Test Beam at CERN SPS in 2007

NINO board performance

- **Noise rate** measured in the lab by varying the discriminator threshold on NINO board: with spare detector module (F406, typical of those installed in ATLAS)
  → RMS noise σ=17mV
- **Efficiency** curve with triggering on an incident MIP measured by varying the discriminator threshold on NINO board
  - median signal with F406 ≈125mV → median S/N≈7.3
  - median signal at 100-130mV with different modules, full threshold range spans 600mV
    → additional amplifier (Mini Circuit GALI-52 500MHz) before digitization, integrated on final NINO boards

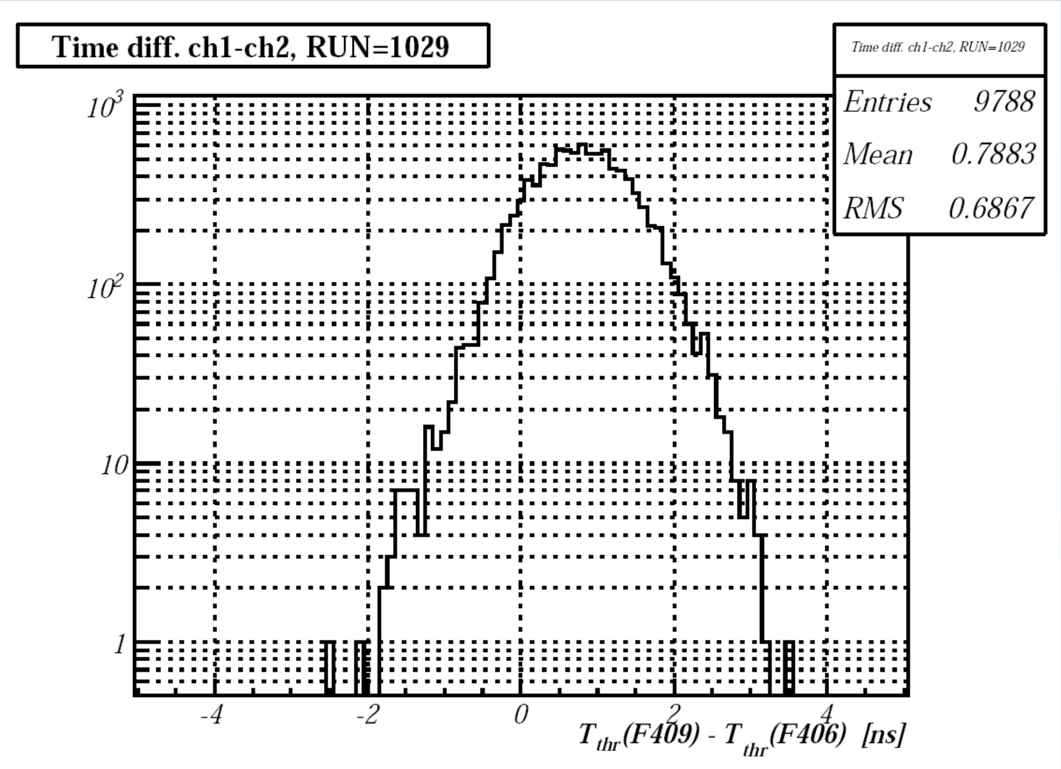




Test Beam at CERN SPS in 2007

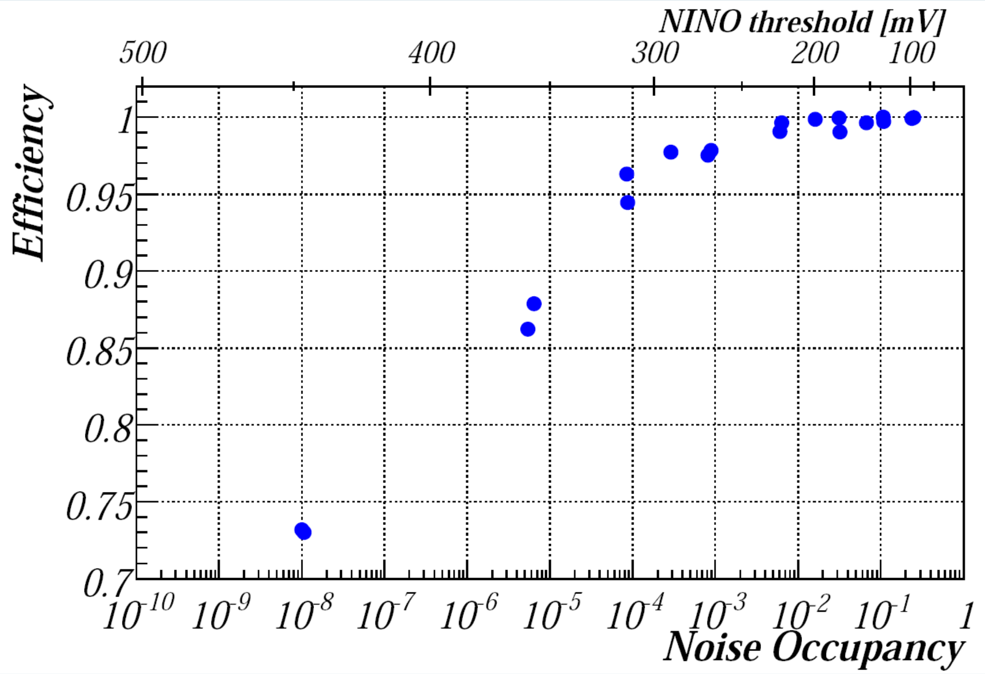
Timing resolution after TOT

- Calculated time difference between NINO pulses (signal crossing half width of NINO pulse height) coming from two detectors connected to ADC
- RMS of time difference distributions bellow 1.1ns for scanned threshold range time resolution for one module < 780ps



Performance of final NINO boards: Efficiency, Noise Rate

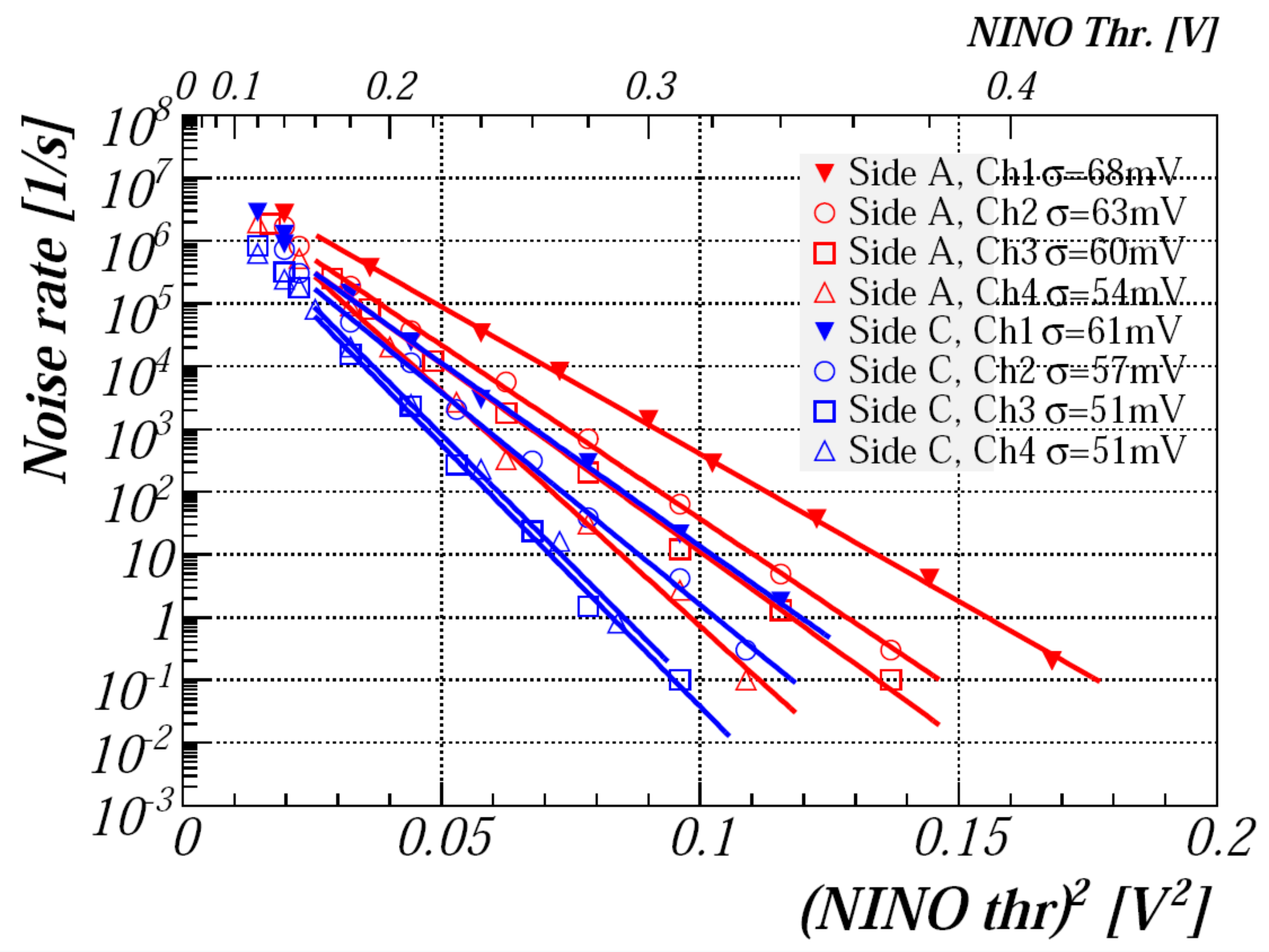
- Noise estimated from noise rate measurement in lab with spare final NINO board and module F406 σ=75mV
- Efficiency curve measured with spare NINO board and module F406
  - ^{90}Sr source, trigger on BCM detector module signal (non MIP efficiency curve)
  - measured curve for final board scaled to curve for 1MIP (scaling factor calculated by comparing test beam and ^{90}Sr measurements obtained for the board tested in test beam): median efficiency ≈ 590mV median S/N≈7.9



- 1MIP efficiency versus noise occupancy (noise rate scaled to 25ns interval – bunch crossing in ATLAS)
  - efficiency 0.95 – 0.99 for occupancies 10^{-3}–10^{-4}
- The exact level of fake rate will depend what kind of logical combination of signals will be used in ATLAS

Performance of installed NINO boards

Noise rate measured in ATLAS pit (after installation of NINO boards in ATLAS)



BLM - Redundant System

- BLM – Beam Loss Monitor
  - Mostly copied from BLM installed in CDF??
  - Sensors:
    - one pCVD 8×8mm^2 diamond, 500µm thick. metallization 6×6mm^2
    - operated at +500V
    - current @500V typically <1-2pA
  - 12 diamonds (6+6) installed on Inner Detector End Plate at pixel PP1 in May 2008
  - 12m coax to PP2 (radiation tolerant BLM cards)
  - Digitization of ionization current in diamond over 40µs, converted to frequency at PP2 (LHC CFC cards, radiation tolerant)
  - Optical transmission to USA15 counting room, recorded by Xilinx FPGA

- Use standalone in case of BCM troubles, otherwise complementary information