Preliminary tests for the development of a beam conditions monitor

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From the Machine interface

Irregular proton losses

Equipment failures
Equipment errors
Operational errors

→ Danger of damage to accelerator components.

In particular: Collimators close to beam!

Beam dump: Designed to extract beam within 2 turns.
Pulse rise time of 3 s (dump gap).

Failure modes:

- Total failure of dump or dump trigger (> 100 years)
- Dump action non-synchronous with dump gap
- Dump action from 1 of 15 modules, others retriggering after 1.3 s.

} Difficult to predict

Assume at least once per year!

RA EPAC02

Magnet failures: V. Kain et al, MOPLE032

Similar accidents at CDF and Phobos

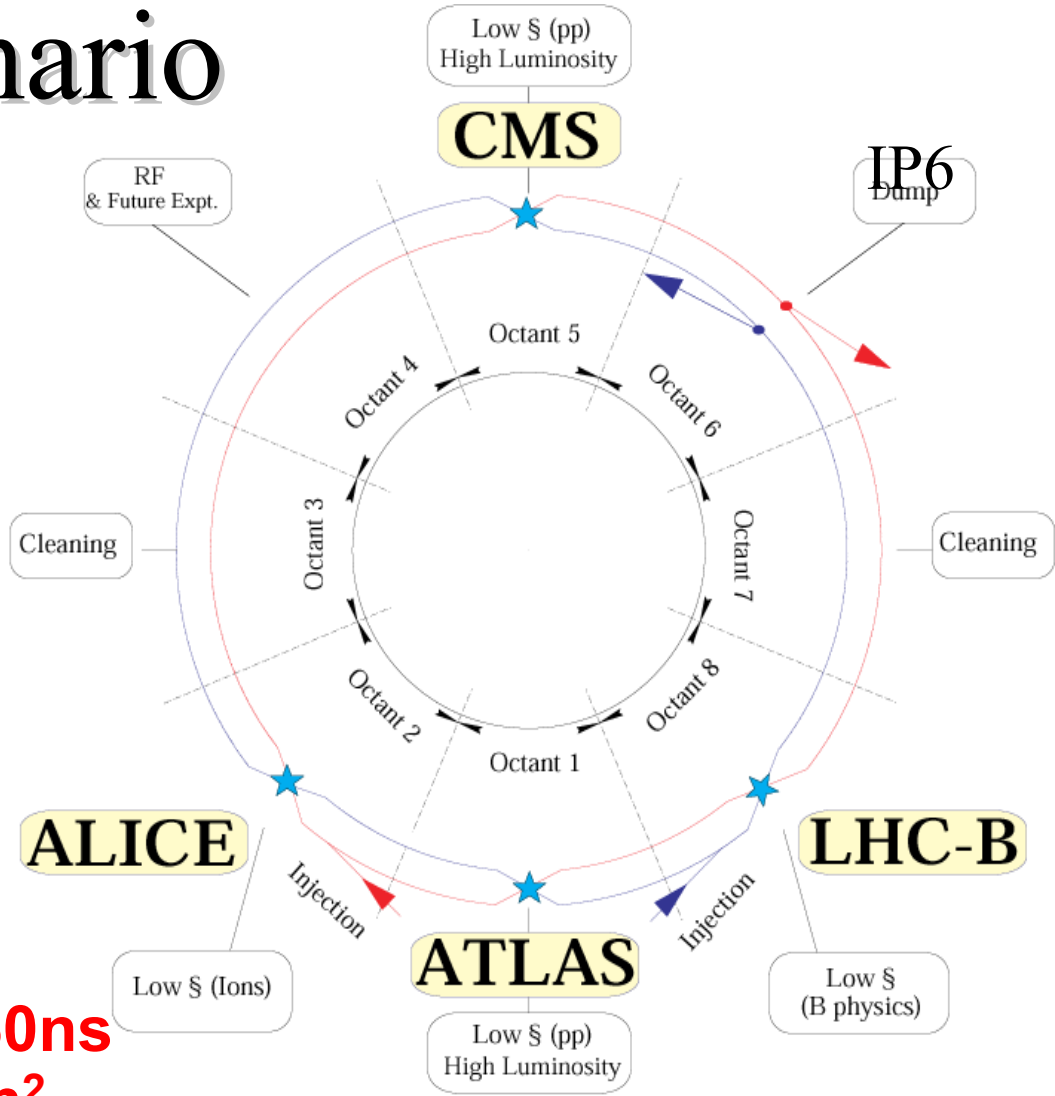
Questions

- **What are the scenarios(normal running, ramping, injection)**
  - **Take unsynchronised abort as the worst case**
- **Can silicon strip modules survive unsynchronised beam abort without damage?**
- **What damage could occur**
  - **destroy coupling capacitor on strips**
  - **Over voltage on low voltage supply**
  - **Short circuit of HV $\Rightarrow$ Pinholes**
- **What is the recovery procedure**
- **Can we build a protection mechanism**

Worst Case scenario

Single module prefire:very unlikely
Assumption only one of the
14 abort kicker fires
=> 4*10^13 protons lost in IP 5

- **Unsynchronized abort**: very likely
  Worst case: one of the dump
  kickers does not hit the abort gap
  => bunch swept out for ~3μs;
  some deviated bunches
  continue in the machine
  => 1*10^12 protons lost in IP 5

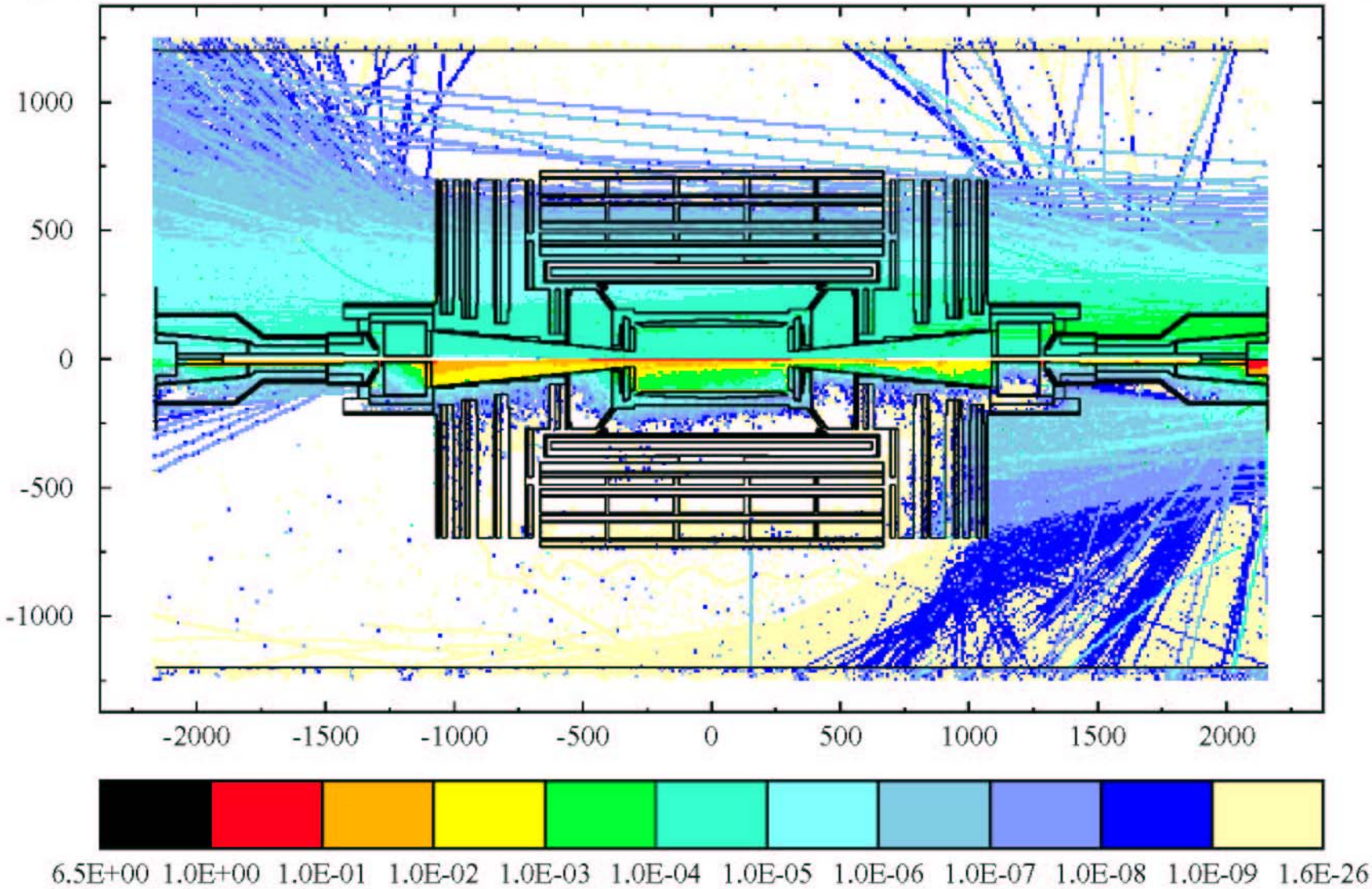


Timescale of accident in CMS ~ 260ns
Characteristic flux 10^9 particles/cm^2

Dose per unsynchronized LHC beam abort (Gy)

Upper half: due to muons, Lower half: due to hadrons

M. Huhtinen



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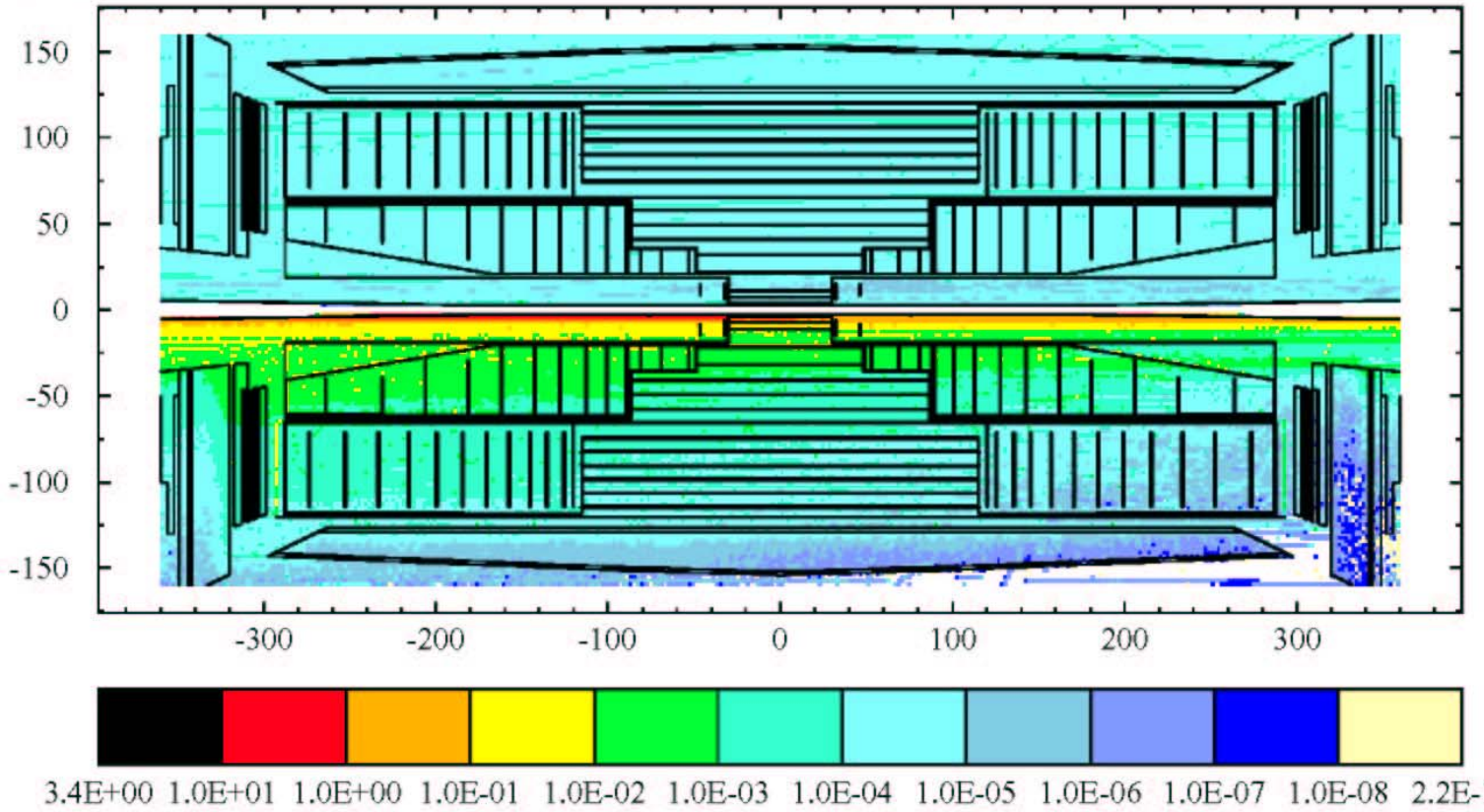


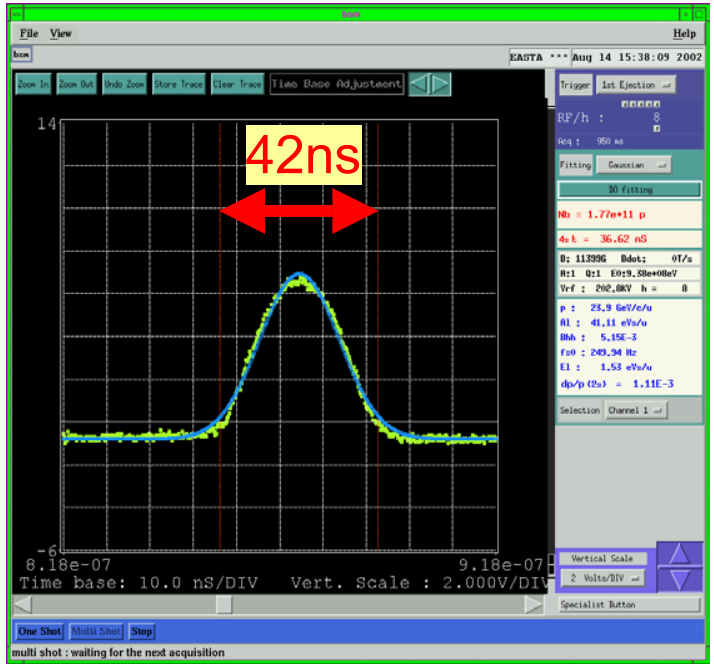
1-Shot test beam at T7 Primary zone

Beam Structure*:* Two beam configurations built from fast extraction from PS

- ***Single bump (1 spill)***
- ***Double bump***

  2 spills separated by 527ns

→ Approximation to beam accident scenarios



Each spill ~ ***3.6 x 10^{11} protons***

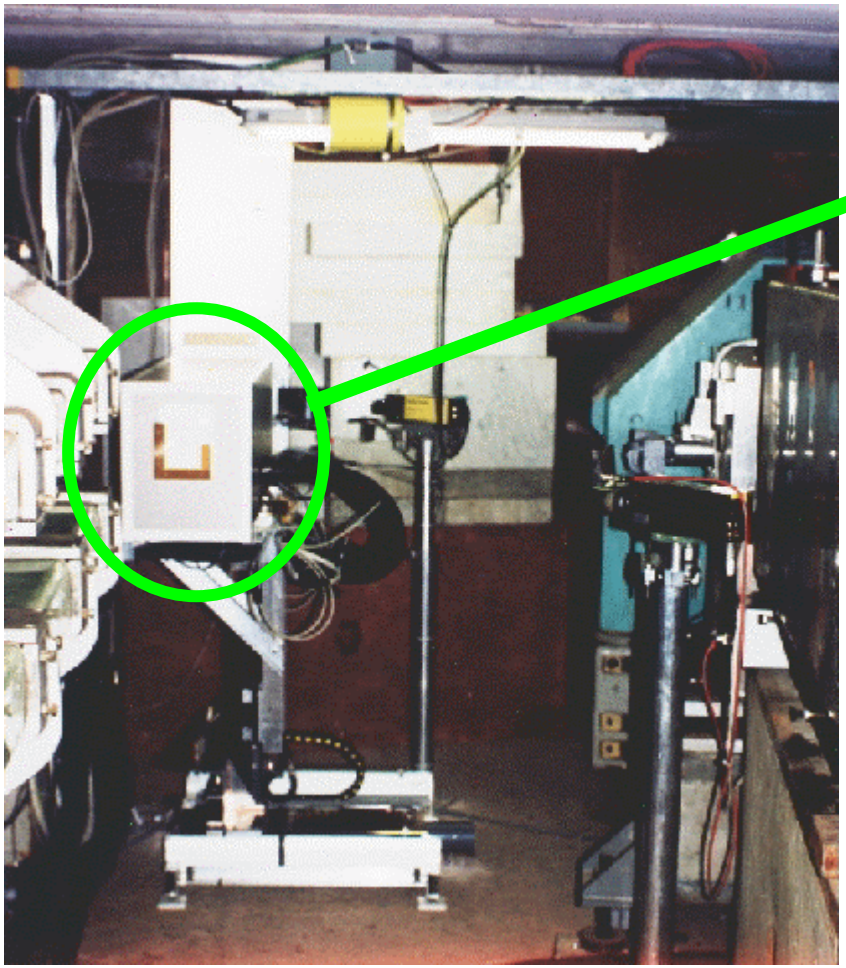
Each spill focus into a large beam spot that completely covers the module. Reason: completely destroy field configuration/depletion across entire silicon sensor

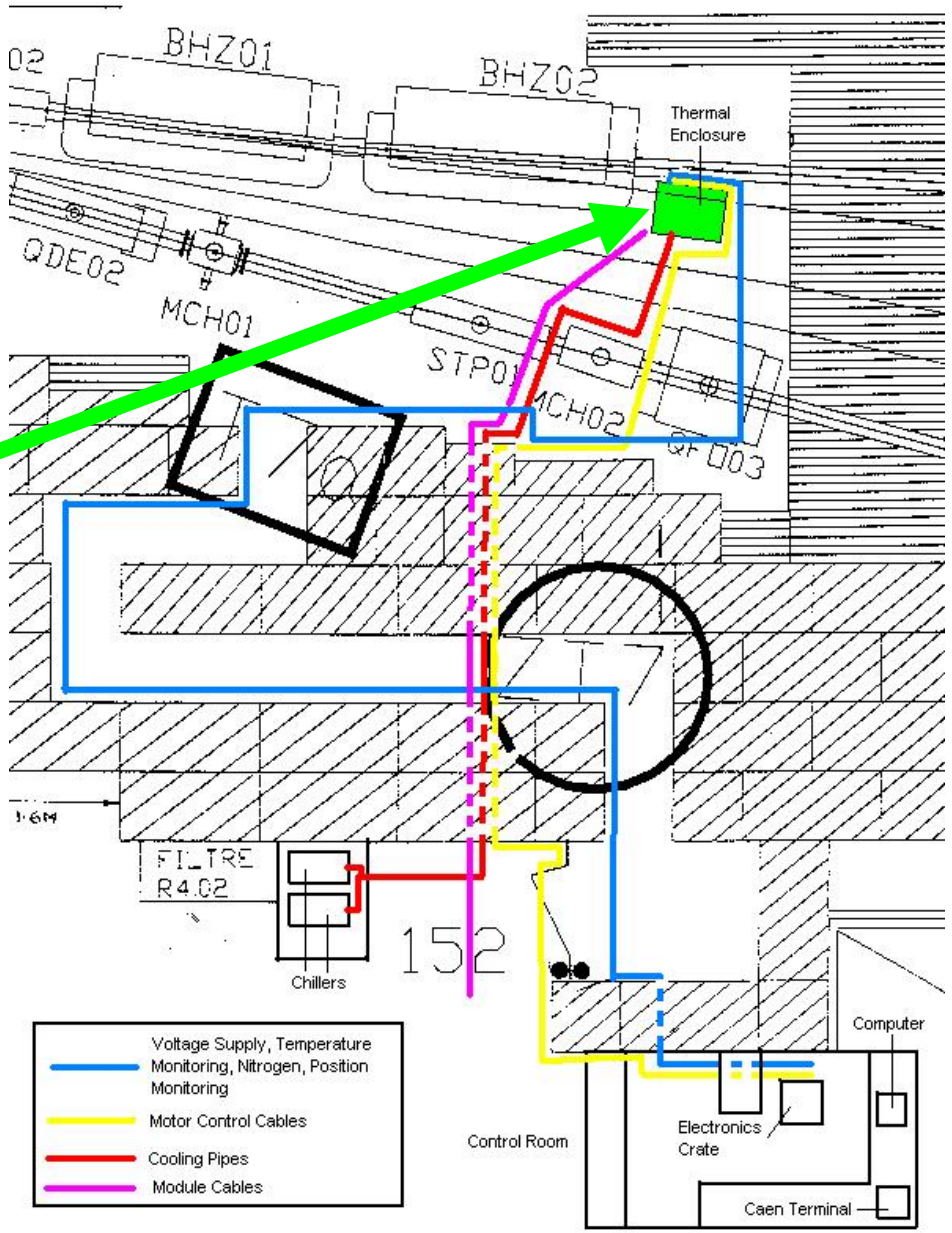
Beam spot = cigar shape 10cm x 3 cm with > *10^9 protons/cm^2*

~ 5x10^9 protons/cm^2 at centre

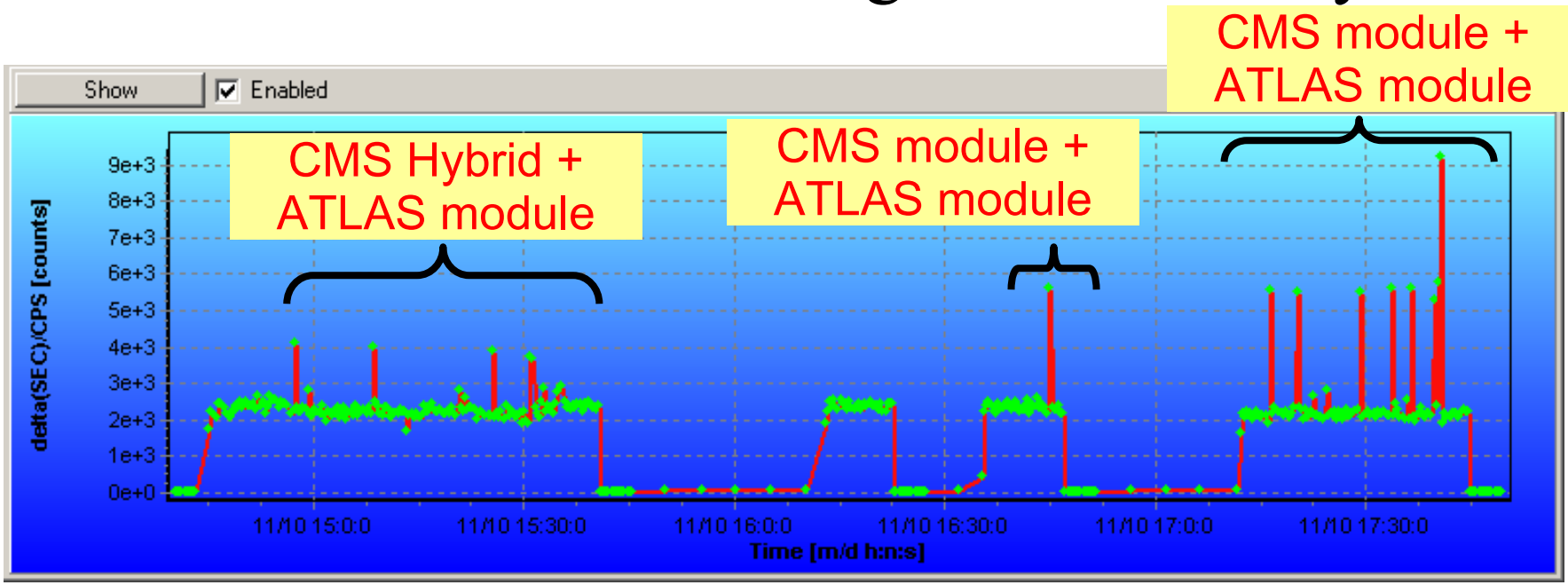
East Hall T7 Area

Primary zone with
24GeV proton beam

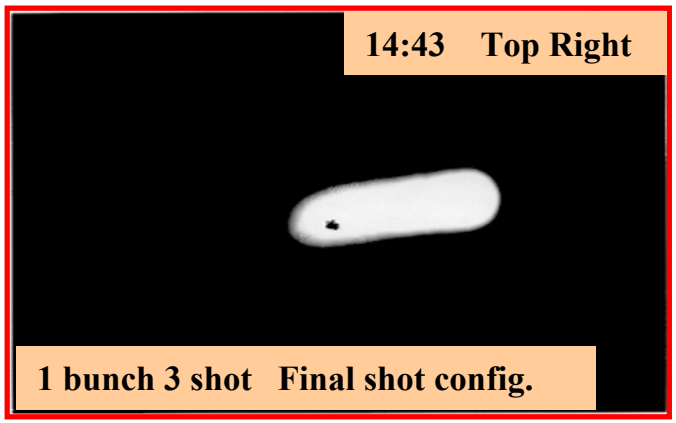




On line beam monitoring and Dosimetry



No.	Start Time	Stop Time	SEC count	# shots	protons	Error
Carbon #C10	4:45:03 PM	4:45:04 PM	3.38E+03	1 (1x2)	1.34E+09/cm2	8.0%
Aluminium #20	4:45:03 PM	4:45:04 PM	3.38E+03	1 (1x2)	1.34E+09/cm2	20.0%
Aluminium #21	5:13:00 PM	5:39:00 PM	2.43E+04	9 (7x2)	7.98E+11	7.0%
Aluminium #22	2:57:14 PM	3:31:14 PM	8.30E+03	5 (5x 1)	6.03E+11	9.0%
Aluminium #23	4:45:03 PM	4:45:04 PM	3.38E+03	1 (1x2)	1.59E+11	9.0%



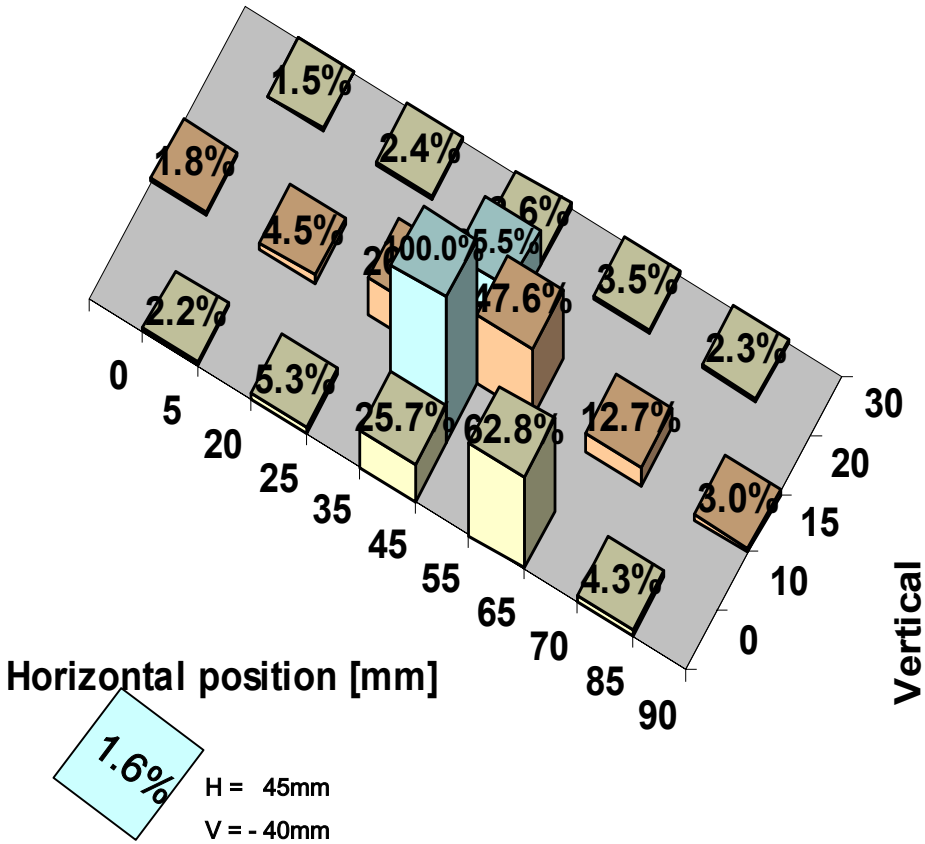
For each run, beam position checked with low sensitivity Polaroids

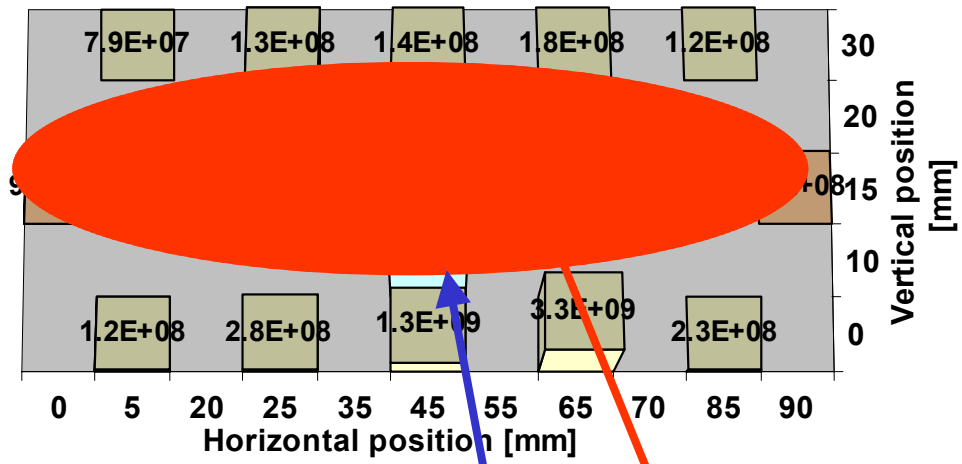
Beam profile in T7

Total fluence =3.62+11 protons 11 October 2002 16:45:04

Dosimetry and profile obtained by ^{11}C with 15 Carbon blocks 10mm^2 x1mm thick

Gamma dosimetry by germanium spectrometer Ge0





Beam spot centre as measured by ^{11}C dosimetry

Central fluence/shot ~ 5.2x10^9 proton/cm^2

CMS setup

1st test: Hamamatsu sensor + hybrid (flex)

- ***Vbias scan: 1-shot (single bump)at 10,100,150,200, 400V***

2nd test: ST-sensor OB2 + TOB module

- ***single 1-shot (double bump) at 400V***

3rd test: Hamamatsu sensor + TEC Express Line module

- ***Vbias scan: one shot (double bump) at 100 - 500V in 100V-steps***
- ***Stress test: 4 consecutive shots (double bumps) at 500V***

Strip parameter on silicon

V_{ACDC} for 3 groups of 5 strips each (Pinhole indicator)

I_{strip} for 3 groups close by (current & Rpoly indicator)

Module / Silicon global parameters

HV as seen by the DUT

I_{leak} via voltage over resistors

Hybrid parameters

V_{125} potential between GND and V_{125}

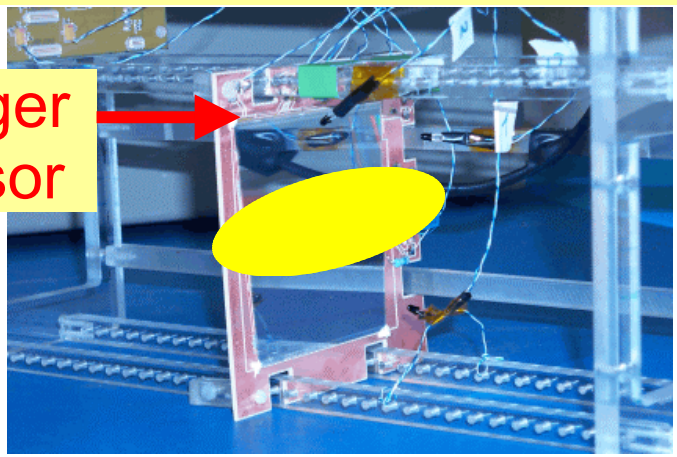
V_{250} potential between GND and V_{250}

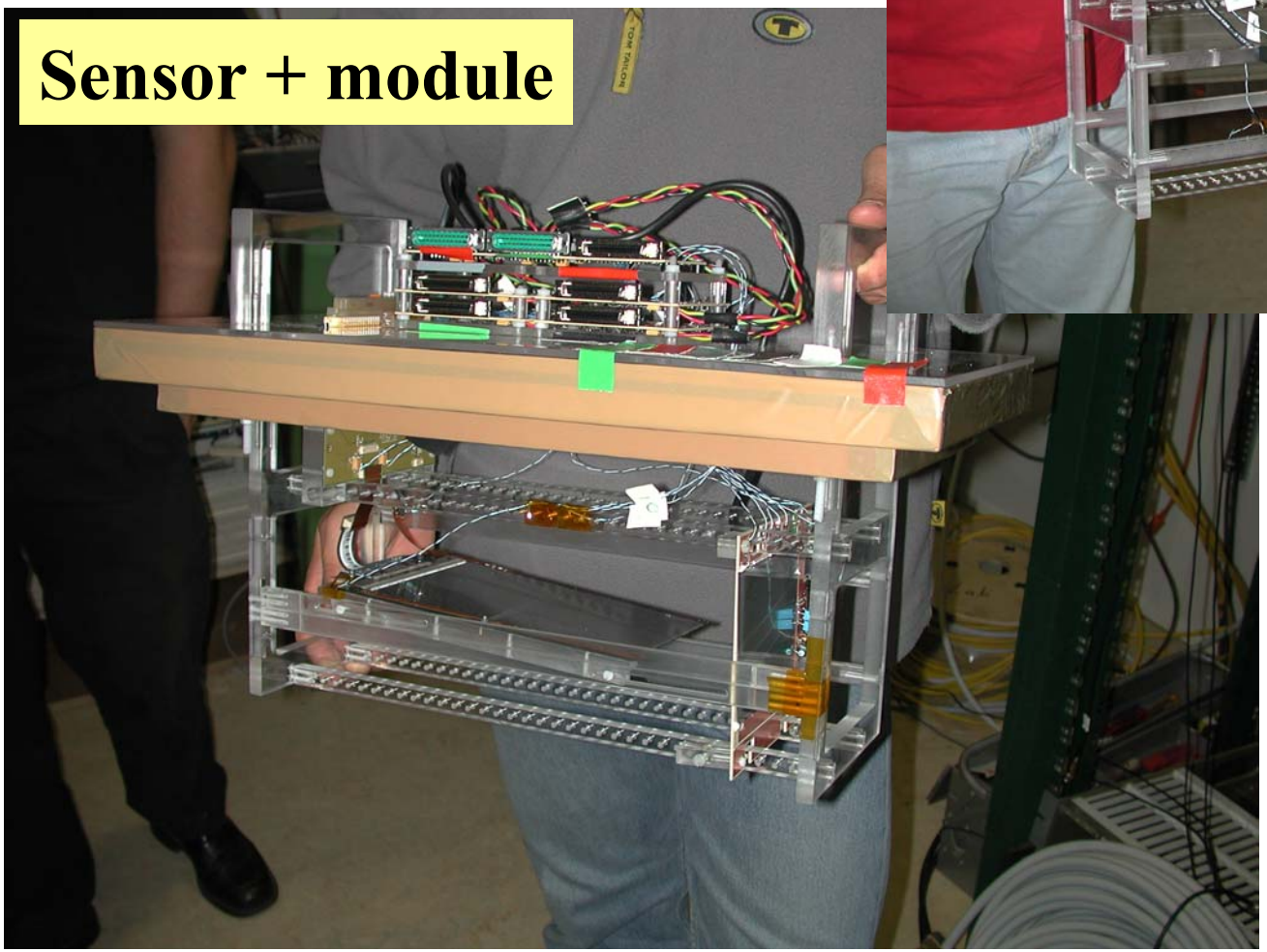
power lines

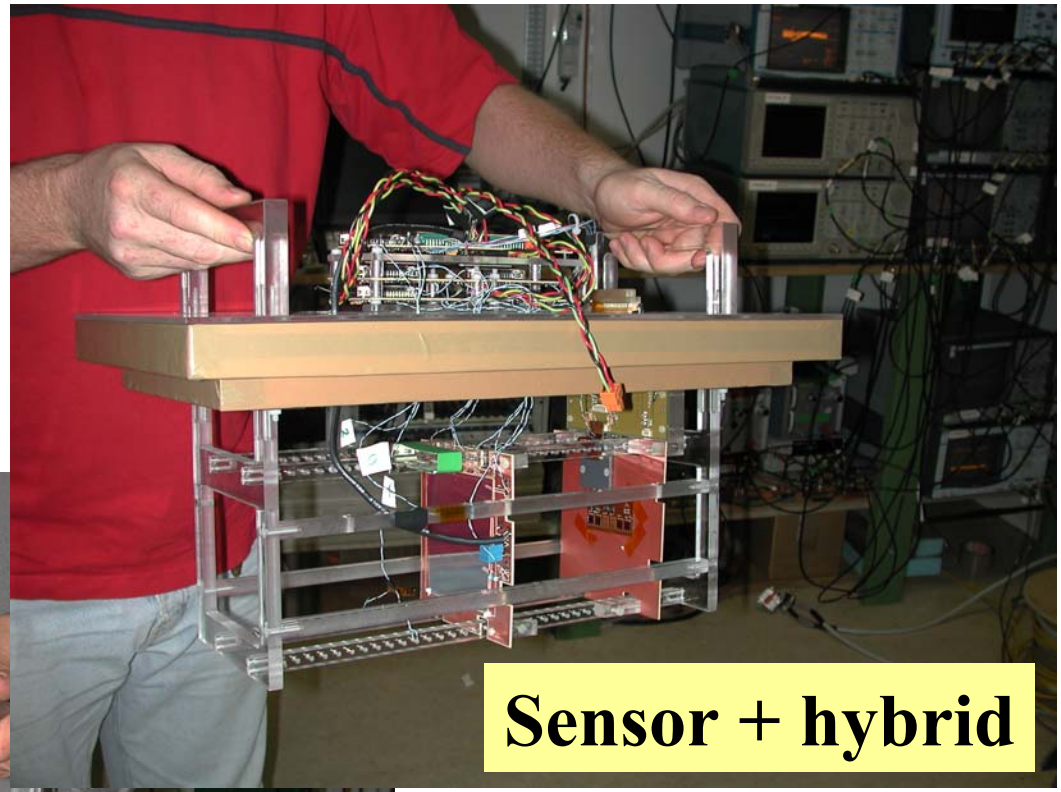
- Sensed LV for FE
- 2 HV lines (module, sensor)

DAQ:

- **38 scope channels. All configured and readout by a single PC.**
- **All running in 20% pretrigger mode**
- **All triggered by sensor leakage current**
- **Optical readout forCMS modules**
- **Electrical readout for ATLAS modules**




Sensor + module

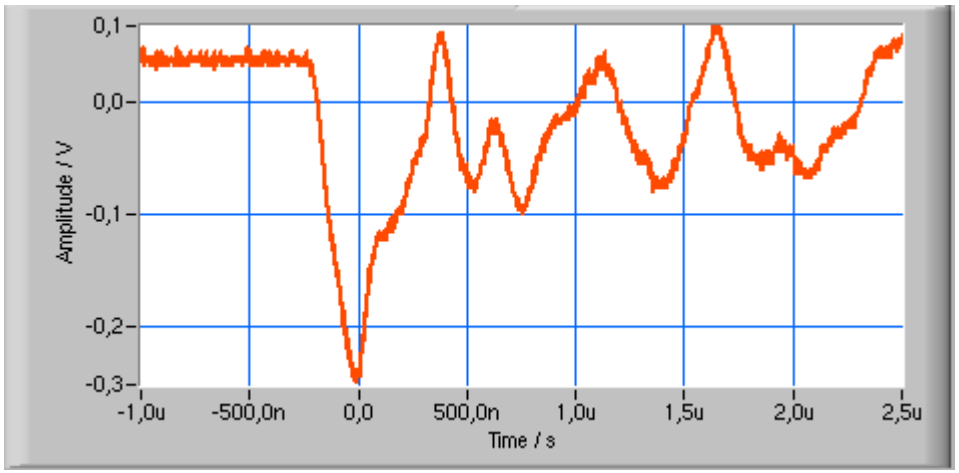

Sensor + hybrid

Beam Structure is visible in Data

Single bump

HPK OB2 sensor

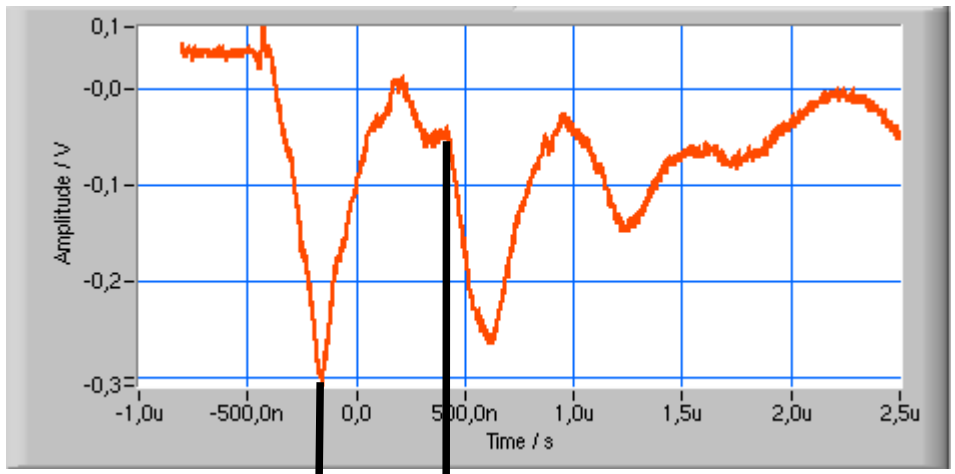
HV breakdown with fast recovery plus add. oscillations



Double bump:

ST W6A sensor

Double HV breakdown



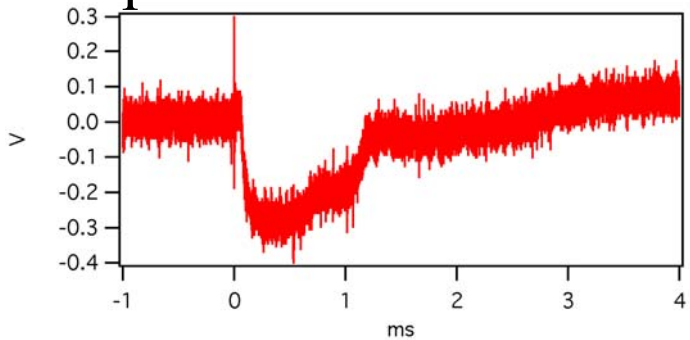
~500ns

Op-Amp in readout with bandwidth of 1us

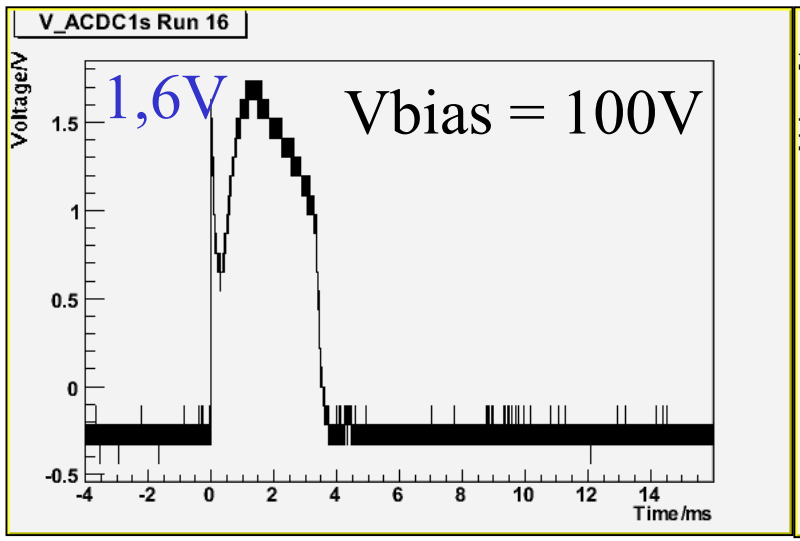
=> Overshoot not real

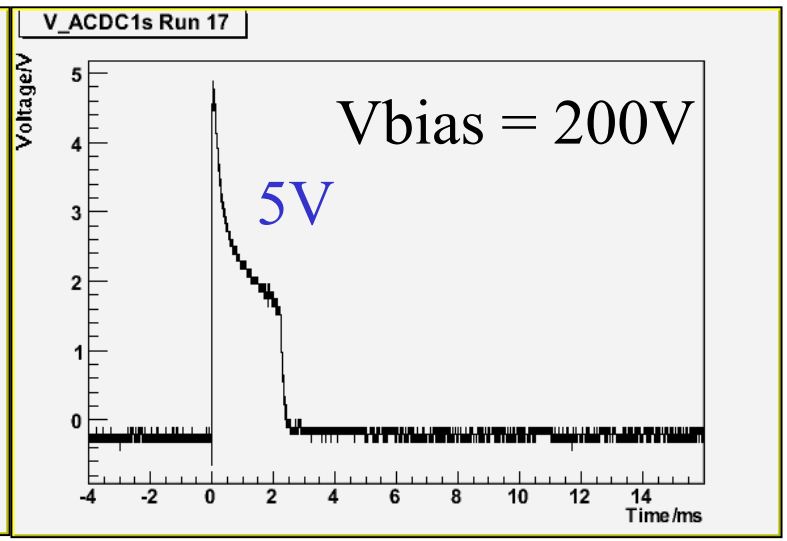
ATLAS SCT

- ATLAS SCT: Electrical test module in standard configuration using 6U VME versions of the final LV and HV power supplies
- 2 configurations tested:
  - with patch panel containing voltage regulators
  - Without voltage regulators
- Results:
  - In all cases the module continued to work normally
    ie answering to commands and reading out.
  - No resets required
  - With voltage regulators, no voltage excursions.
  - Without voltage regulators, observed voltage excursions on the millisecond time scale
    - 0.3 and 0.1 V excursions on VDD and VCC resp.
    - 6V excursion on the detector HV

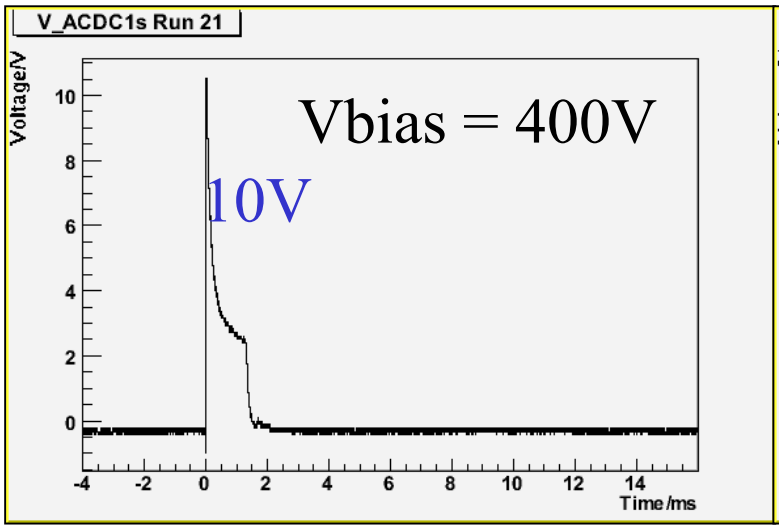


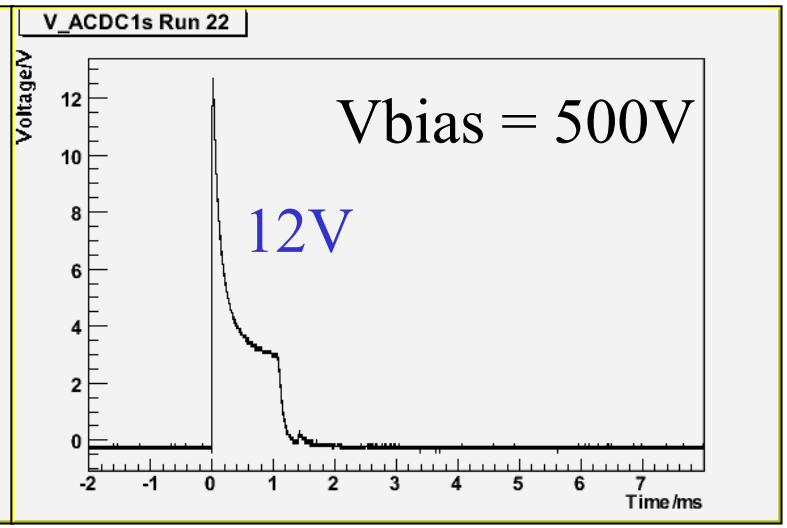
CMS:Voltage across coupling capacitors: V_{AC-DC}





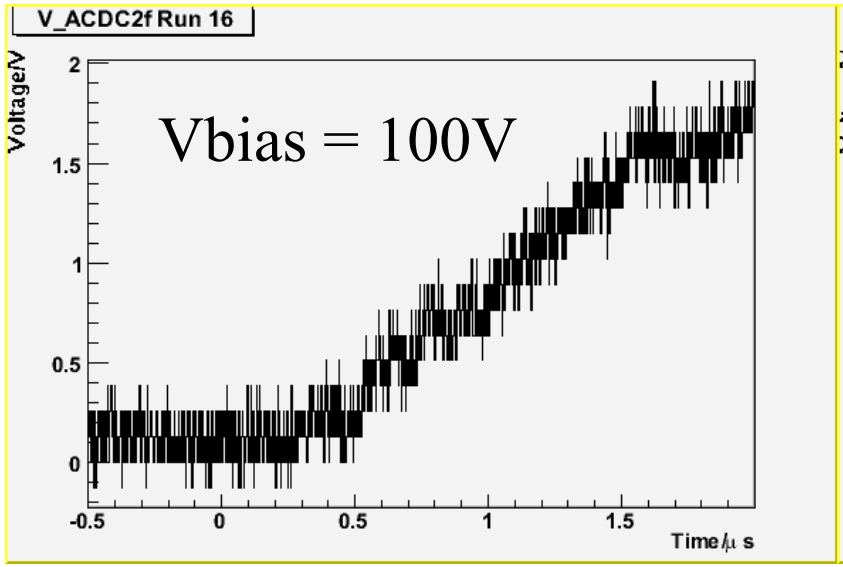
The increase is visible but nowhere critical!

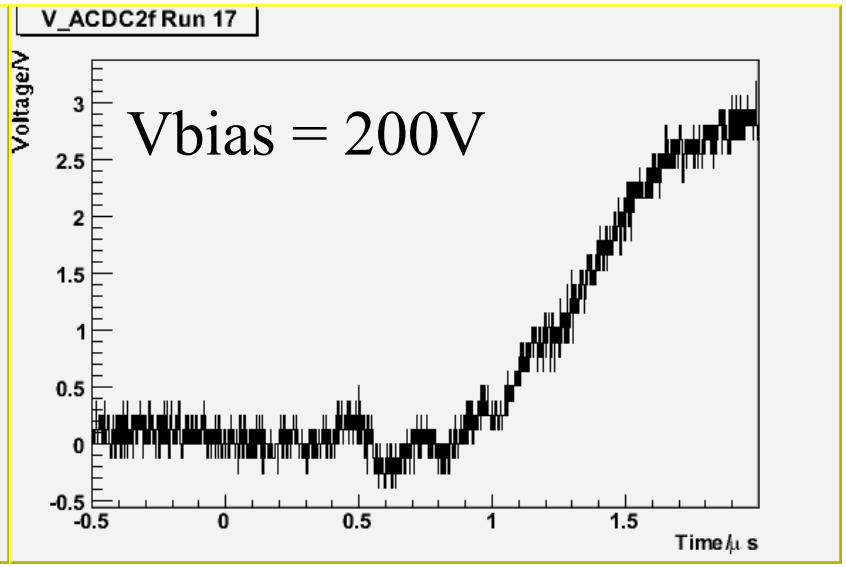


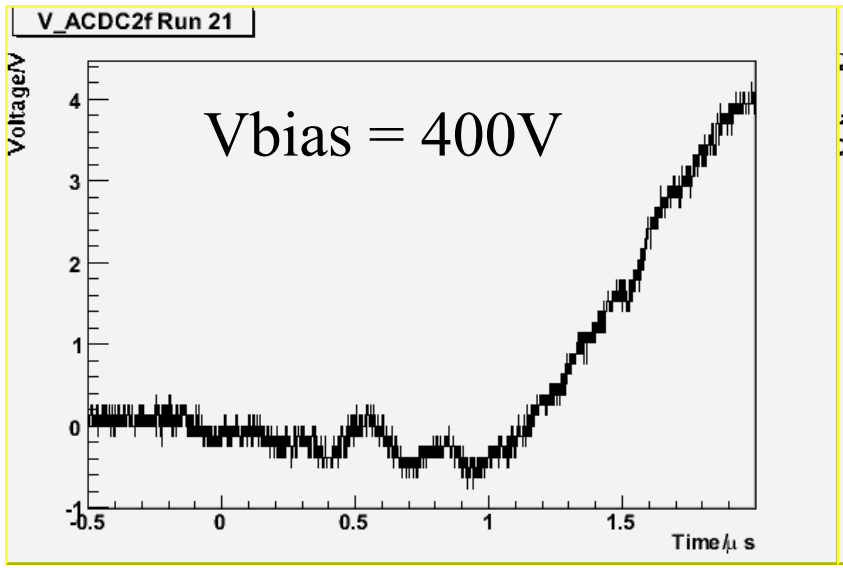


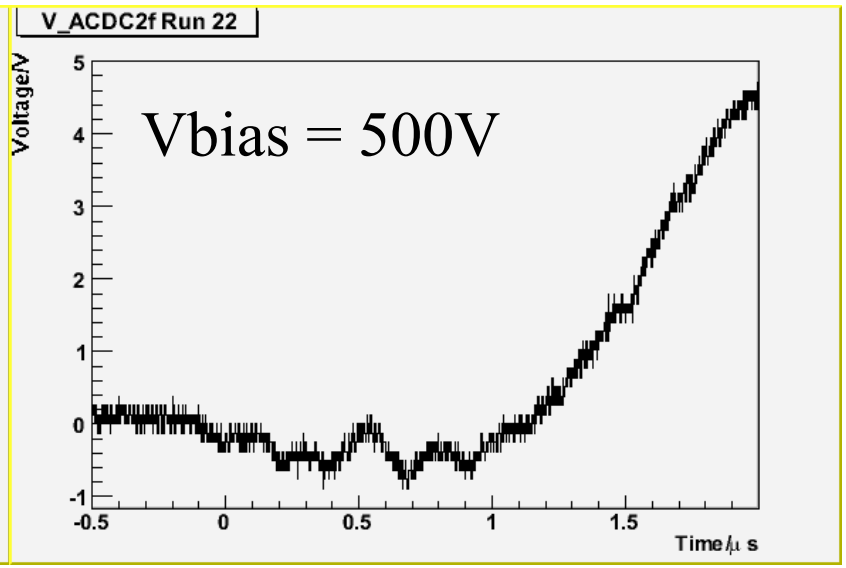
We took these voltages at 3 different places! Same result (~10%)

Fast view of V_{AC-DC}









V_{ACDC} starts ~1 μs after the 1-shot.

No problem with spikes observed

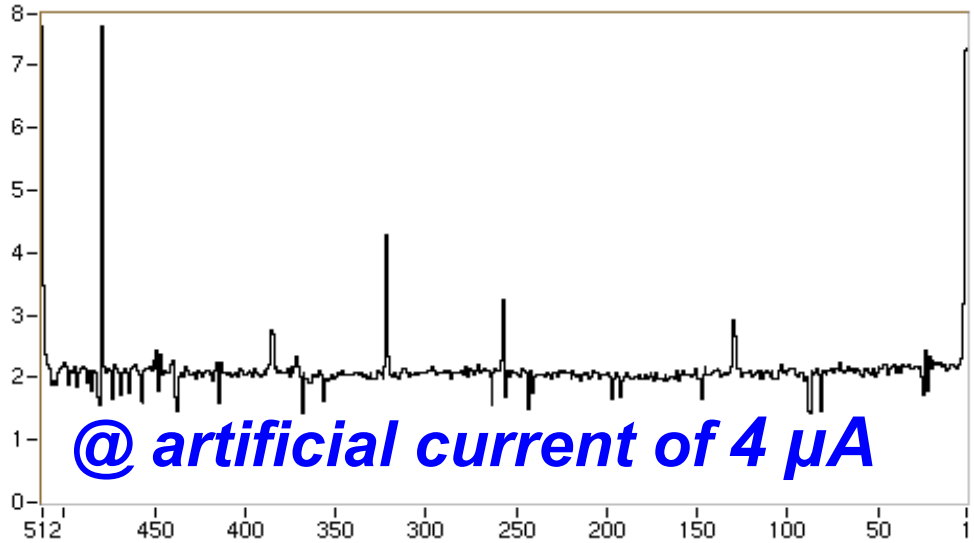
CMS TOB Module

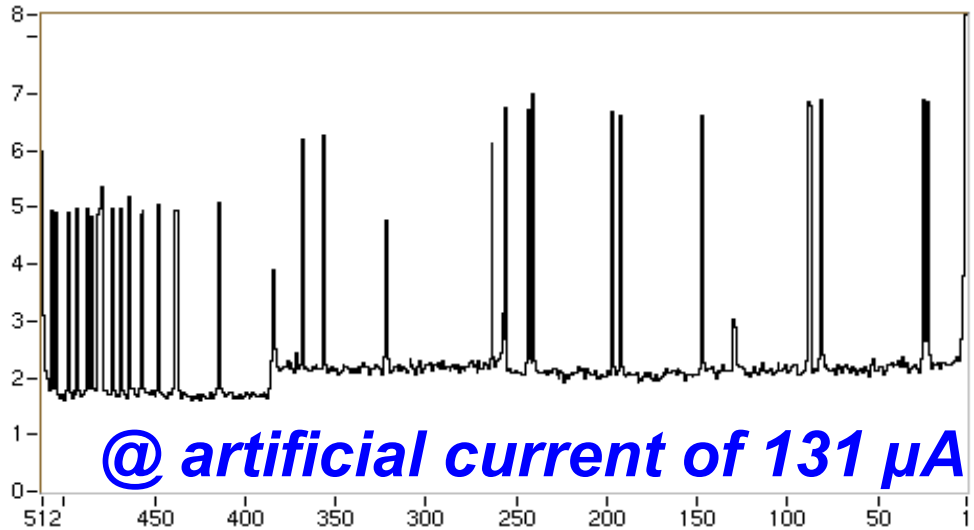
32 pinholes after one shot with Vbias = 400 V!

Before: 7 bad channels
X5: only some noisy & dead channels

‘***Old***’ TOB module with M200 sensors from ST used, ***WITHOUT*** the add. SiNitrate in the dielectric (old pinhole problem).

noise



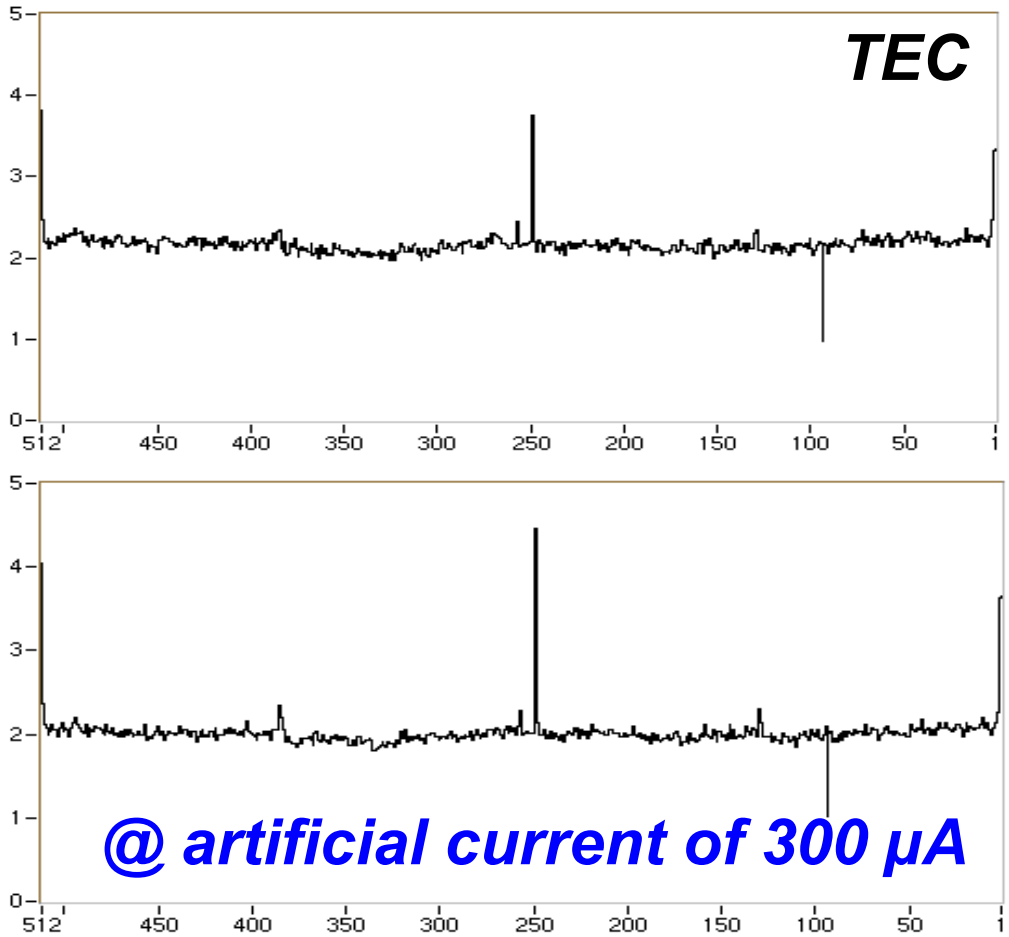


CMS TEC Module

TEC production module:
works fine after a total of 9
“beam dumps”
(including 5 shots @ 500V)

Also no problems with:
Pedestals & Calibration

noise



Sensor requalification

Measurements on Hamamatsu and ST sensors shows:

- slightly increased ***leakage current***
- good ***CV curves***
- ***NO additional pinholes for HPK & ST***
  (30 strip sample each)
- ***all strip parameters are still in specs***

Some measurement problems due to mounted & glued sensor

Summary of 1-shot tests

- Hybrids
  - 5 shots without power +1 shot with power on
  - all without clock & I2C

  Postqualification in Strasbourg with FHIT shows a perfect working hybrid.

Modules

- survived the electrical stress
- Fast recovery in the range of ms.
- Only soft reset needed
- Fast recovery of electronics and readout

Pixel System Considerations

Dose: ~1 Gy per accident. Corresponds to ~E12 protons

$\Rightarrow$Unsynch beam abort =>1×10^{-12} Gy/p.

In 10 years of normal operation CMS pixels expects ~1MGy

$\Rightarrow$Dose rate = 1MGy/5×10^{7} s = 0.02 Gy/s (normal operation @1E34.

Assume beam condition monitor with 100 ns integration time

Normal operation: Monitor sees 2×10^{-9} Gy in 100ns

Unsynch beam abort $\Rightarrow$loss of $2 \times 10^{-9}/10^{-12}$ = 2000 protons in 100ns

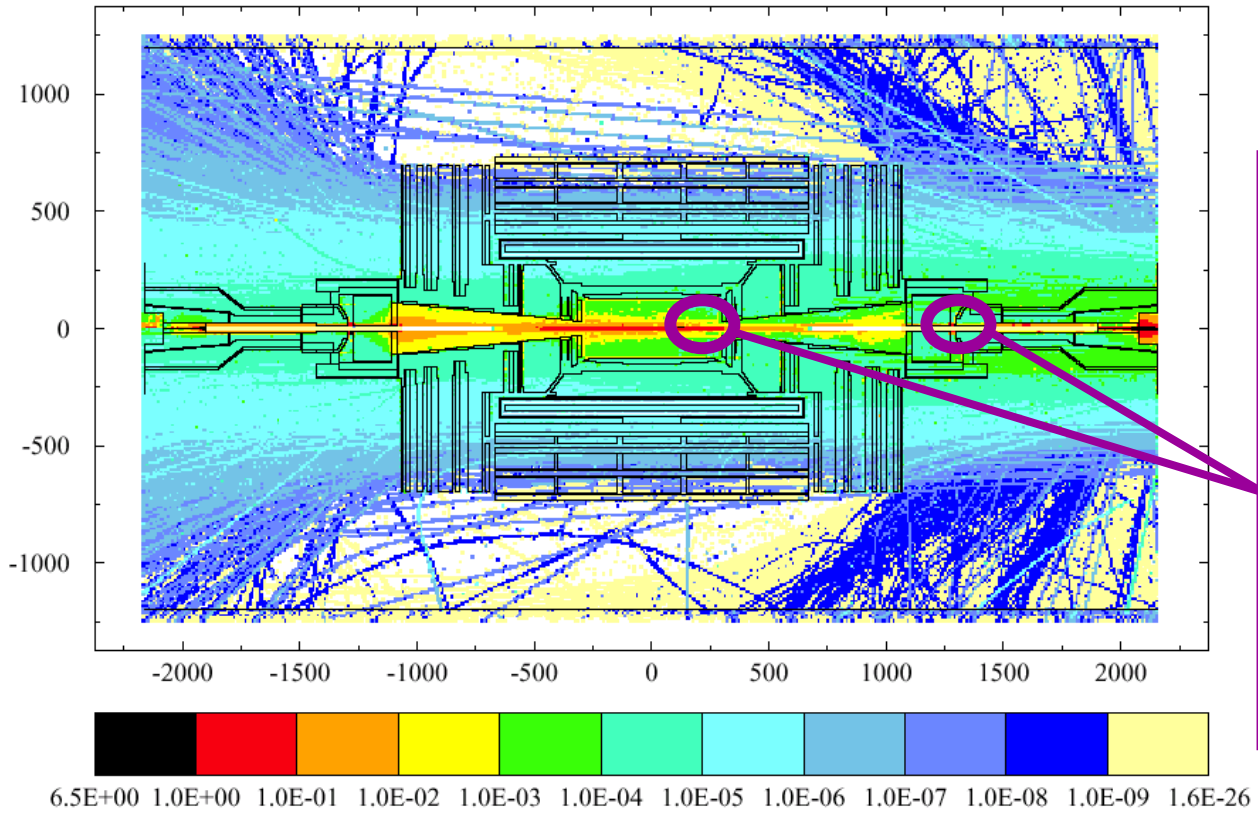
Put a threshold at 1000 protons/100ns. Use to detect fast loss

Power supplies should be able to react on 250 –1000 us

Look to detect fast beam instabilities.

Slowly developing ones difficult to distinguish from the pp-rate

$\Rightarrow$ rely on Machine Group



Beam condition monitors

Looking for increase over normal rate

Monitors to be within CMS volume and feed into machine interlock

Two options being considered to date:

- CVD diamond with 0.25 um readout chip, and readout integrated into pixel system
- Quartz fibre with dedicated opto readout

Very much preliminary: to early to report details