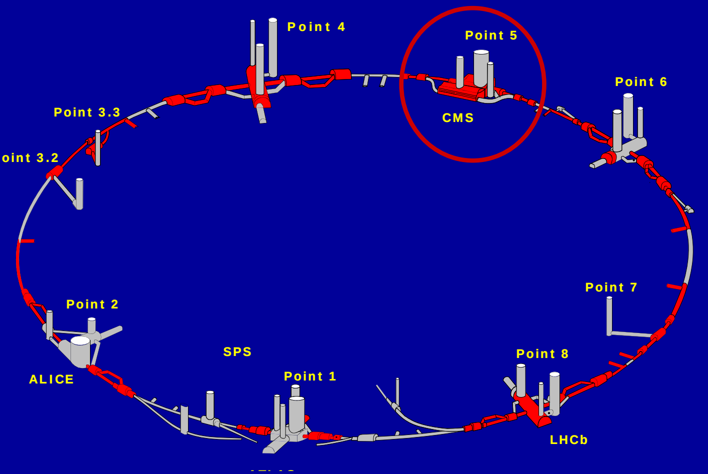
The CMS Beam and Radiation Monitoring

Wolfgang Lohmann, DESY

Functions

- monitoring of the beam induced radiation (UXC55 and adjacent straight sections)
- monitoring of the machine status, define conditions to safely operate sub-detectors
- real time fast diagnostics of beam conditions, initiate protection procedures in case of dangerous conditions for the CMS detector

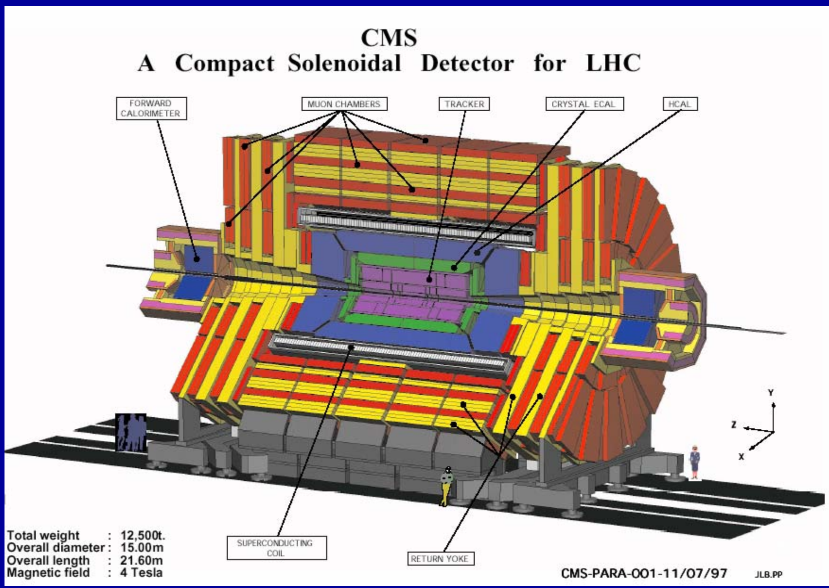
LHC und CMS



Proton-Proton Wechselwirkungen, 7 TeV x 7 TeV
Physik auf der "Tera Skala",
Hoffnung auf Entdeckung des Higgs Bosons
(Ursache der Ruhemasse), neue Teilchen, neue Symmetrien

Energie: 10 x Tevatron
Luminositaet: 100 x Tevatron
Neue Anforderungen an
die Kontrolle der Strahlen
und des Strahlhintergrundes

LHC und CMS



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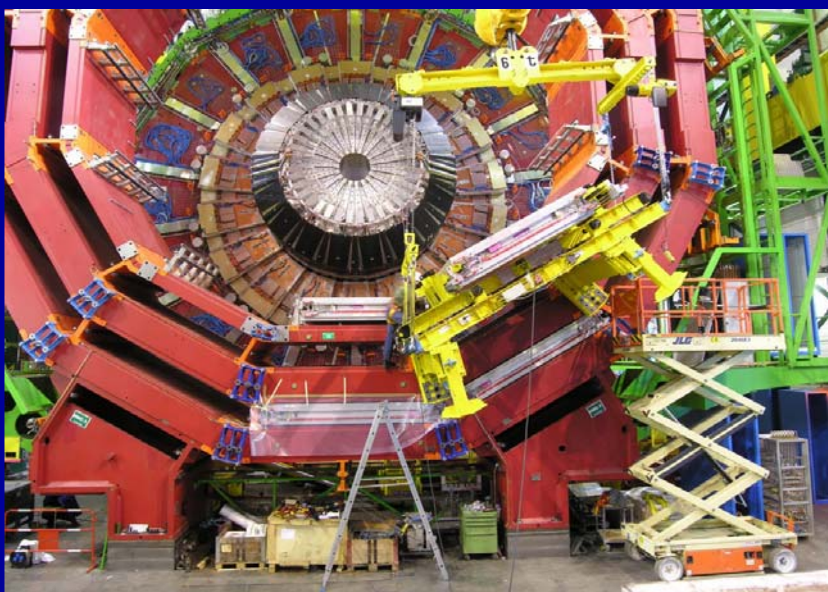
LHC und CMS



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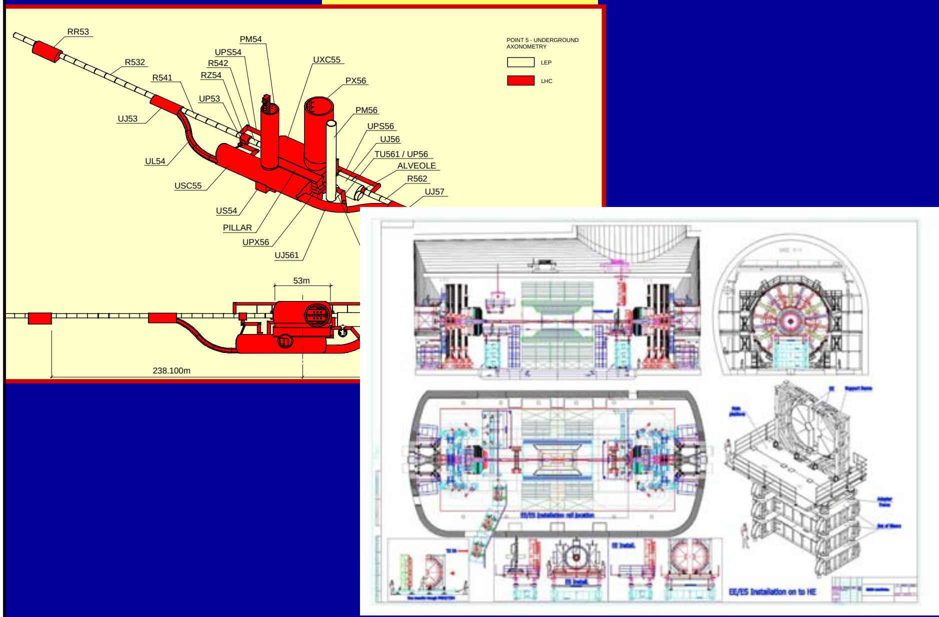
LHC und CMS



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CMS-BRM

The BRM group is run as a sub-project within CMS technical coordination

Auckland, Canterbury, CERN, DESY-HH, DESY-Zeuthen, Uni Karlsruhe, Princeton, Rio de Janeiro, Rutgers, Tenessee, UCLA, UC-Davis, Vienna, Uni Hamburg

About 40 people, 8-10 at CERN

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CMS-BRM

Be aware

-Before LHC starts filling the BRM must be operational to ensure safely running of the detector,
-During data taking BRM is needed to ensure high 'usable' luminosity

En Detail

- Must be active whenever there might be beam in LHC
- Ability to initiate beam aborts
- Warning and abort signals to CMS subdetectors, ie. ramp down HV, LV
- Integration of online beam information into CMS, LHC control and data taking
- Post-mortem analysis, e.g. after beam loss
- Benchmarking of integrated dose and activation level calculations

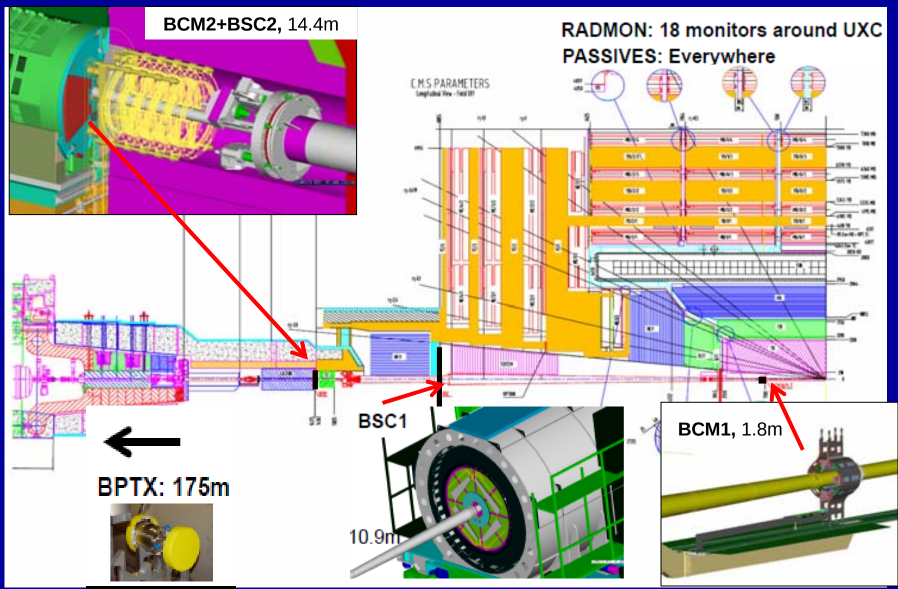
The components

Subsystem	Location	Sampling time	Function	Readout + Interface
Passives TLD + Alanine	In CMS and UXC	Long term	Monitoring	---
RADMON	18 monitors around CMS	1s	Monitoring	Standard LHC
BCM2 Diamonds	At rear of HF $z=\pm14.4$m	40 us	Protection	CMS + Standard LHC
BCM1L Diamonds	Pixel Volume $z=\pm1.8$m	Sub orbit ~ 5us	Protection	CMS + Standard LHC
BSC Scintillator	Front of HF $z=\pm10.9, 14.4$ m	(sub-)Bunch by bunch	Monitoring	CMS Standalone
BCM1F Diamonds	Pixel volume $z=\pm1.8$m	(sub-)Bunch by bunch	Monitoring + protection	CMS Standalone
BPTX Beam Pickup	175m from IP5	200ps	Monitoring	CMS Standalone

Factor 10^{17} in time resolution

-Systems are independent of the CMS DAQ and LHC UPS power

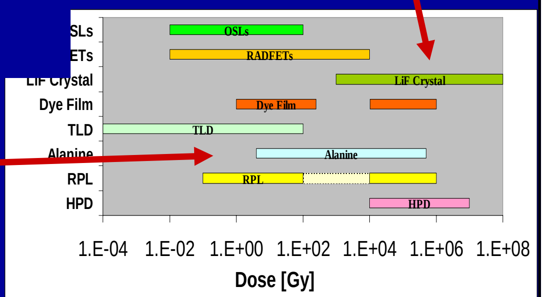
The locations



Passive Monitors: TLD (Thermo Luminescent Dosimeter) and Alanine (PAD)

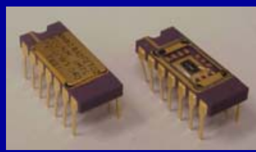
TLD uses LiF, photon sensitivity over a wide energy range, Accumulated energy is stored as transition to metastable states. Heat releases the energy via light emission
^{6}Li captures neutrons with large cross section, the recoil products contribute to the excitation

Alanine is a n aminoacid, ionising radiation creates free radicals. Dose measurment using EPR (e paramagnetic resonance)analysis



RADMON

- 18 Monitors deployed around CMS, close to equipment and shielding, to measure:



•Dose and doserate using RadFETs
trapped charge in gate oxide

•Hadrons (E > 20MeV) flux, SEU rate via SRAM
radiation induced voltage spikes in a reversed bias p-n junction

•1 MeV equiv. neutron fluence using pin diodes, fluence of a with E>100 keV
Conductivity variation

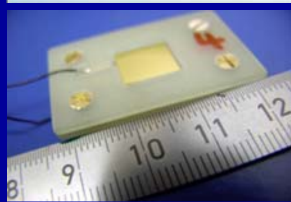
SIEMENS
BPW34

-Data reported to the RADMON database
-Used as online benchmark points for the verification of simulations

CVD Diamond Sensors

CVD polycrystalline diamonds are produced as disks with radii up to 10 cm

Single crystal up to a few mm^2

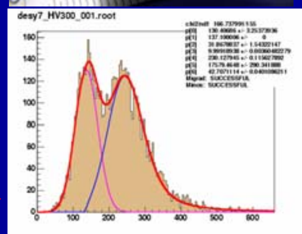


Sensors are made as cm^2 pieces, 150 -900 μm thick, metallized at both sides (Ti-Pt-Au) and then operated as a "solid state ionisation chamber"

Interesting features:

-high thermal conductivity
-high electron/hole mobility
-low ε (5.7)
-radiation hard

Problems:
-small released charges, for pCVD limited charge collection efficiency
-small size, expensive



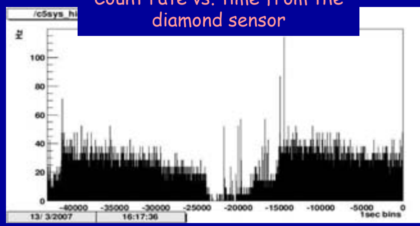
Typical spectrum of a Mip

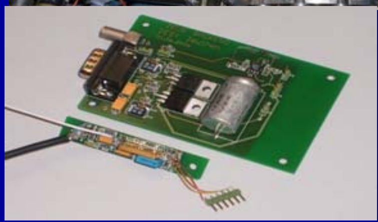
CVD Diamond Sensors, our experience with ZEUS

Operation of a single crystal diamond near the HERA beampipe and comparison of the count rate with ZEUS beam monitor (Sasha Ignatnko)

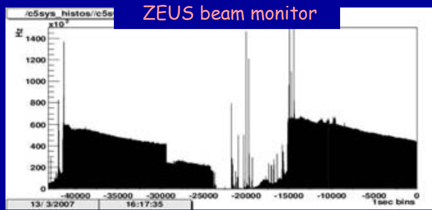
Sensor with preamplifier

Count rate vs. time from the diamond sensor





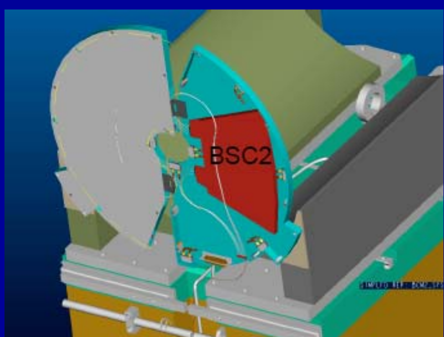
ZEUS beam monitor



Stable operation over half a year (monitored with a mip signal)

BCM2, Diamonds

Fully assembled sensor, 1x1cm^2, 500μm thick



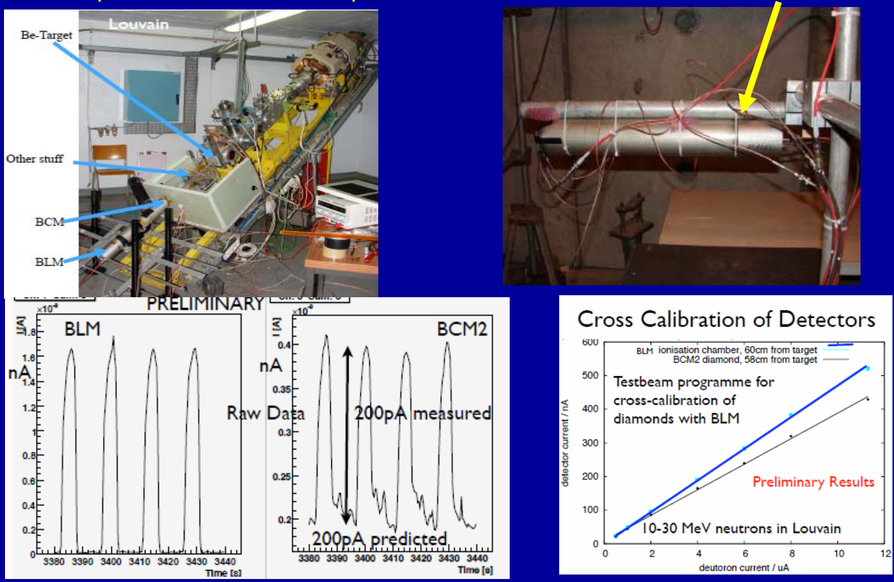
Mounted on Castor installation table
z=14.4 m, R=5 and 29 cm

4 inner sensors sensitive to IP products
8 outer sensors sensitive to incoming background (shielded against the IP)

Readout: 25 kHz, 40μs, standard LHC beam loss monitor electronics,
Active from day 0, included in abort decision

BCM2, Diamonds

Comparison of diamond response with a LHC beam loss monitor (BLM)



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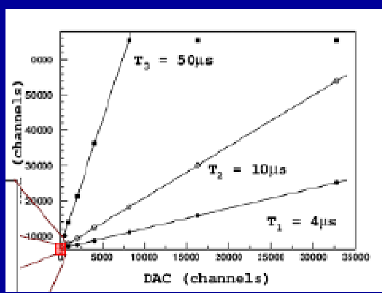
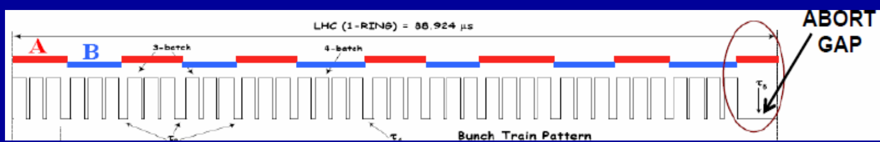
BCM1L, Diamonds

Same sensor type, current measurment,
z = 1.8m, R=4.5 cm

Readout: 200 kHz (5μs) no FE electronics





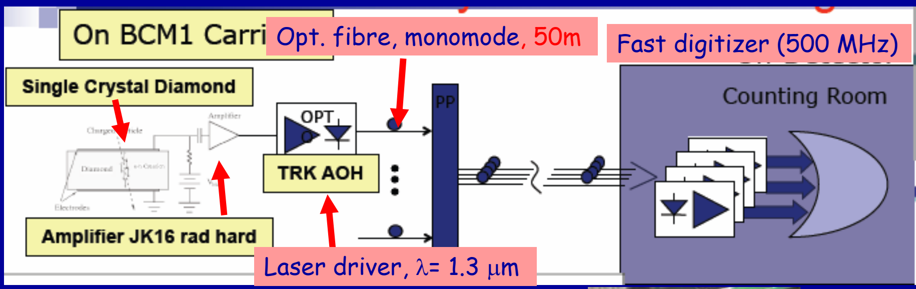
Synchronised sampling over the LHC bunch train structure and abort gap
Enable beam permit

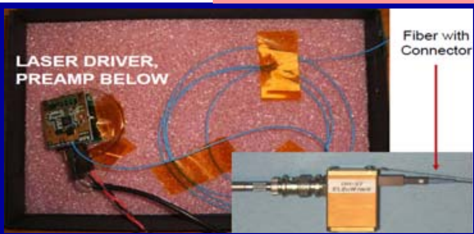
CVD diamond sensors are metallized at Rutgers
Characteristica are measured at DESY
Assembled in Karlsruhe → CERN

BCM1F, Diamonds

Four single crystal CVD diamond sensors, size .25 cm² @ z=±1.8m, r=4.3 cm

Readout chain:

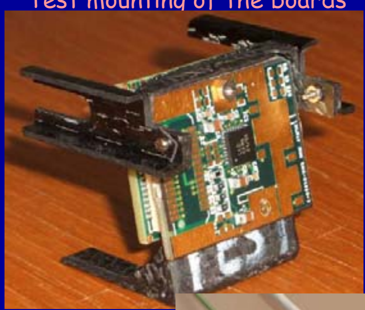




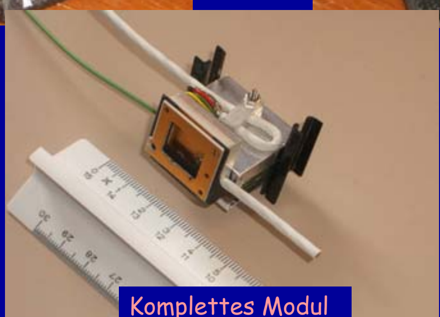
Optical receiver (Optobahn)

BCM1F, Diamonds

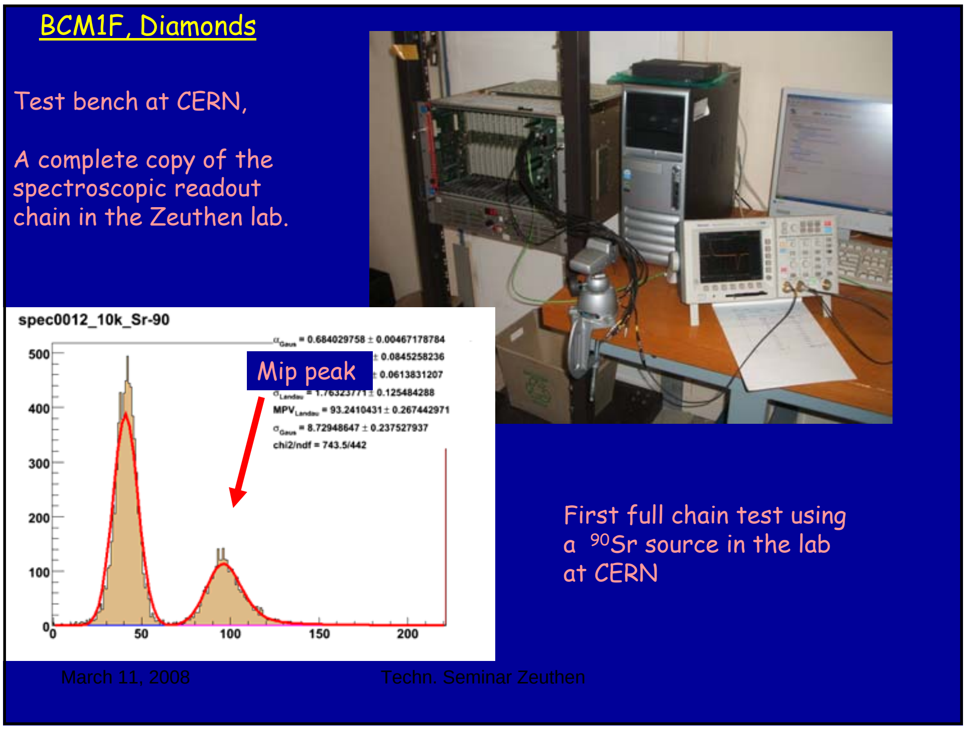
Test mounting of the boards



Place for the diamond crystal



Komplettes Modul



BCM1F, Diamonds
Test bench at CERN,
A complete copy of the spectroscopic readout chain in the Zeuthen lab.
spec0012_10k_Sr-90
σGaus = 0.684029758 ± 0.00467178784
± 0.0845258236
± 0.0613831207
MPVLandau = 93.2410431 ± 0.267442971
σGaus = 8.72948647 ± 0.237527937
chi2/ndf = 743.5/442
Mip peak
First full chain test using a ^{90}Sr source in the lab at CERN
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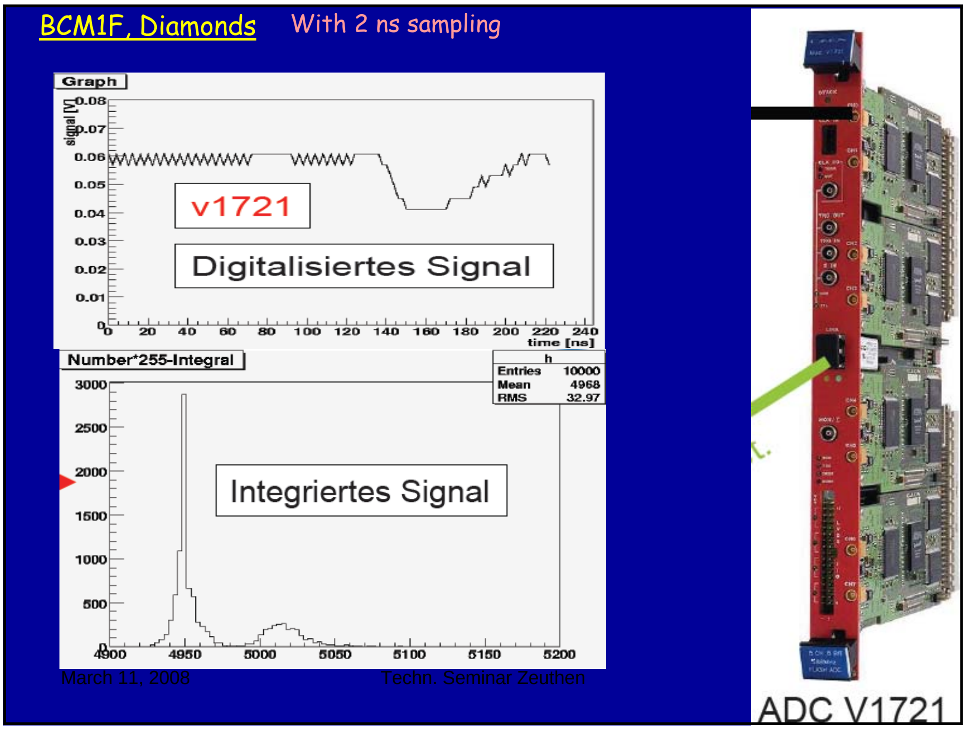

BCM1F, Diamonds
With 2 ns sampling
Graph
signal [V]
time [ns]
v1721
Digitalisiertes Signal
Number*255-Integral
h
Entries 10000
Mean 4968
RMS 32.97
Integriertes Signal
ADC V1721
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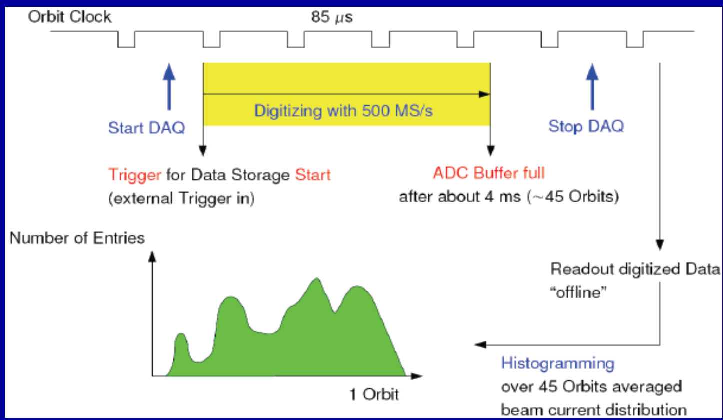
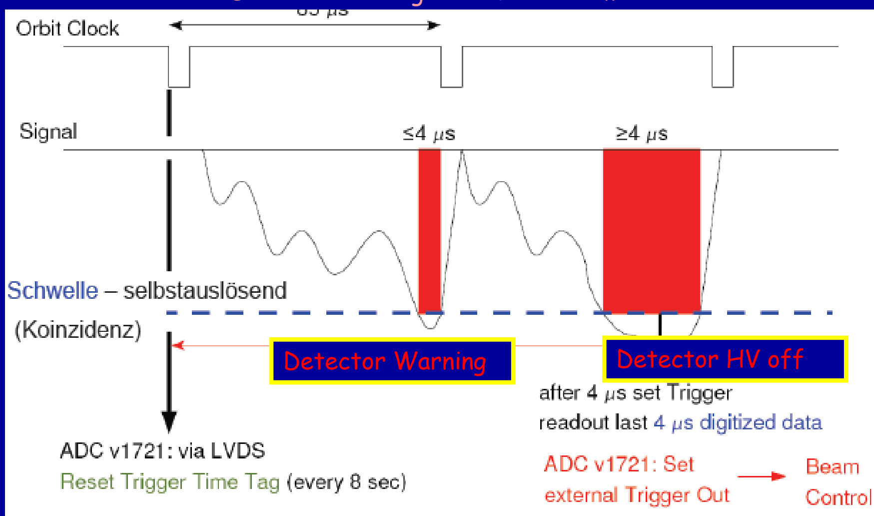
Beam Orbit Diagnostics



Beam orbit diagnostics

Detector Warning and Shut down Mode

Detector warning and shut down mode



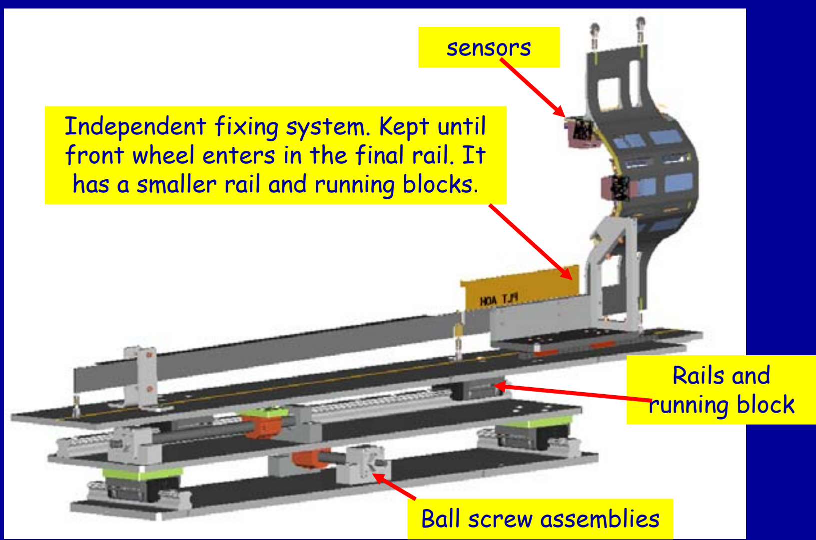
BCM1F, Diamonds

The next topics to complete the commissioning including montage:

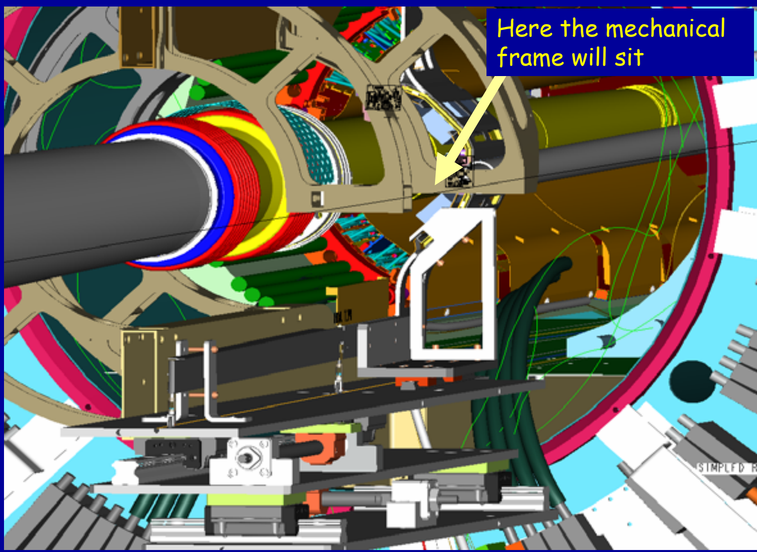
- Complete and test FE the 8 readout chains
-Replacing the C.I. ADC by Flash ADCs (500 MHz)
-Configure the controler and PC software to extract the important information to display in the counting room, to set limits for subdetector background level and ensure post-mortem beam diagnostics.
-complete hard- and software test in the lab.
- montage in April
- debugging

For software development/debugging an identical system will be set up at DESY

BCM1F, Diamonds



BCM1F, Diamonds



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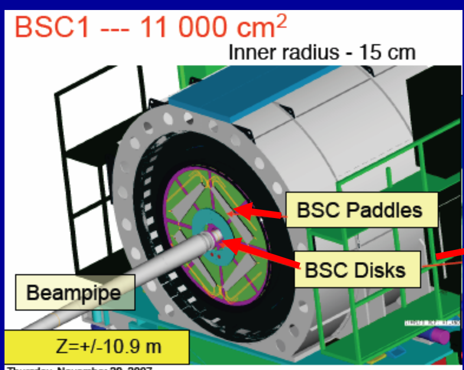
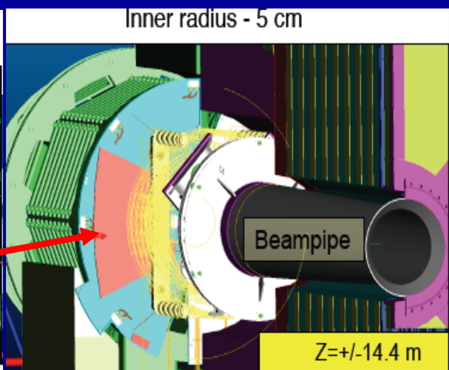
Beam scintillation counter (BSC)





BSC are forseen as a commissioning tool, first 1-2 years

Replacement (e.g. diamond sensors) depending on experience in the first operational phase

No FE electronics, mip sensitive, same back end as BCM1F
Single hit time resolution 1-2 ns

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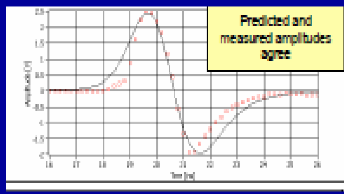
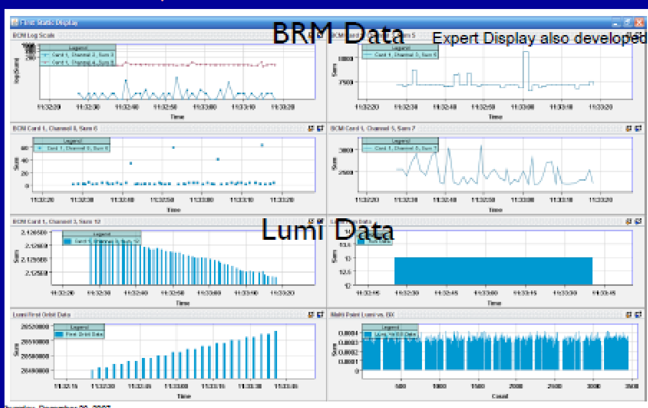
Beam pick up (BPTX)

- Analog signal, 200 ps sampling
- Measures the phase between bunch and 40 MHz (bunch) clock,
- IP position
- Checks filling scheme, bunches in the correct RF buckets
- Check that abort gap is empty
- Check for satelite bunches
- Measure charge of each bunch



BRM DATA Display

Developed with AB/CO, combined
Display with Lumi Group

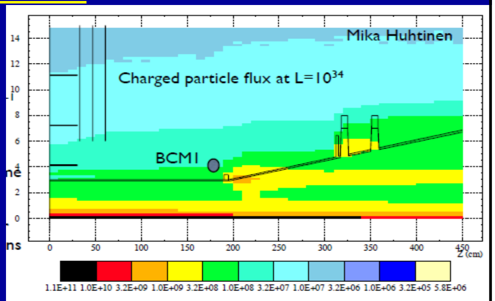


Display will be part of the DESY remote Control Centre at DESY, plus a display for details of the BCM1F data

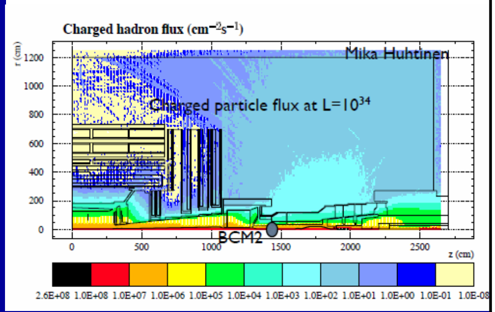
Dose and rate estimate from Monte Carlo

Expected diamond currents at Nominal Luminosity

BCM1, 1 cm^2
-estimated rate: 1-3.2 10^8 $cm^{-2}s^{-1}$
-expected signal current: 200 nA
about 200 times higher than noise



BCM2, 1 cm^2
-estimated rate: 10^8 $cm^{-2}s^{-1}$ inner
$10^6 cm^{-2}s^{-1}$ outer
-expected signal current:
100 nA inner
1 nA outer



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CMS-BCM

There are Milestones:

-Completion of the Tests at DESY: beginning of March

-Completion of BCM1L Commissioning: mid April

-Installation: Mid April

-Debugging before first beam

In case the system will work- nobody will complain;
Otherwise, we are in big trouble ……

We use "Synergy" between FCAL (ILC detector R&D) and CMS
-Application of diamond sensors in a harsh environment
- fast readout and luminosity optimisation

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