LHC Workshop on

Experimental Conditions and Beam Induced Background

What the experiment provide and require for optimization

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Acknowledgments: M.Ferro-Luzzi, C.Ilgner, R.Jacobsson, K.Hennessey, M.Lieng, V.Pugatch, A.Schopper, D.Wiedner

Setting the scene

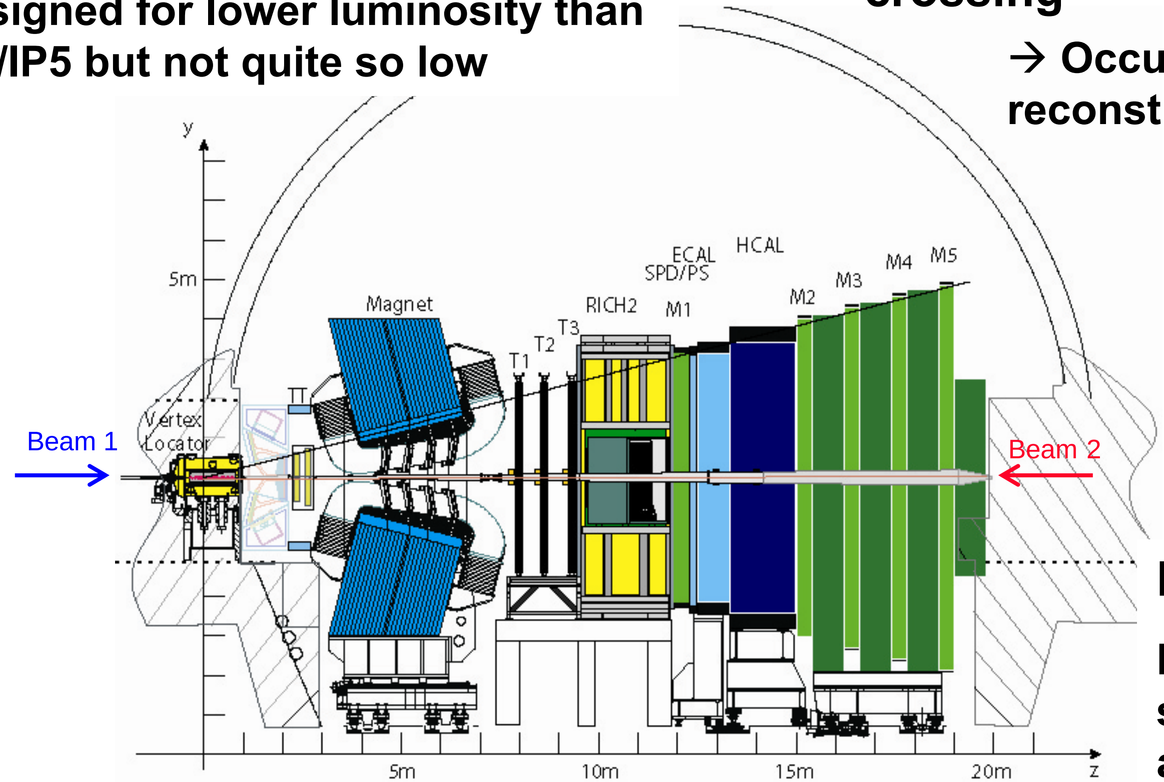
$L_{ave} = 2.0\ (/5.0) \times 10^{32}\ cm^{-2}\ s^{-1}$

Tunable: $1 \leq \beta^* \leq 50$

Luminosity chosen to maximize number of single interactions/bunch crossing

→ Occupancies (i.e. trigger and reconstruction)

Designed for lower luminosity than IP1/IP5 but not quite so low



Forward detector:

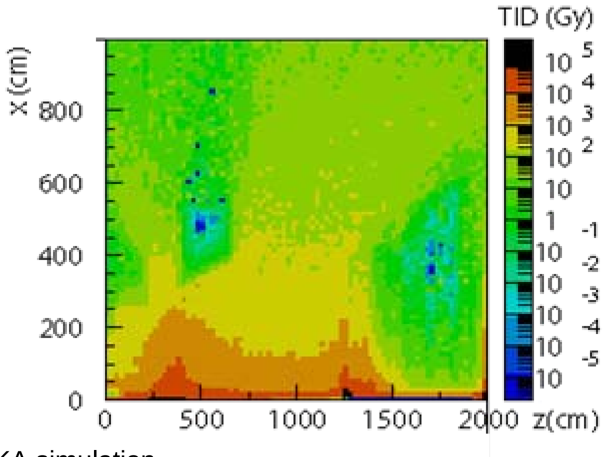
Beam1 and Beam2 are NOT seen the same way by trigger and physics - Timing

Shields in tunnels close to VELO and Muon System, but they have been staged

Dipole magnet → internal crossing angle

Radiation levels

Radiation levels dominated by pp collisions



FLUKA simulation
L.Shekthman

Radiation level in
Bending plane over
5 years 2×10^{32}
+ 5 years 5×10^{32}
$[1/(cm^2 s)]$

Radiation resistance requirements for 10 years at 2×10^{32} cm^{-2} s^{-1} with safety factors

VELO and Silicon Tracker: 0.1 MGy and $\mathcal{O}(10^{14})$ 1 MeV neq cm-2

Machine induced background for beam1 from the tertiary collimators (V.Talanov)

Lifetime 30h with nominal machine→ Loss rate 3×10^9 p/s in IR7 (3×10^6 p/s on TCT)
→ 2×10^6 charged particles(h+μ)/s at LHCb cavern with currently installed shield.

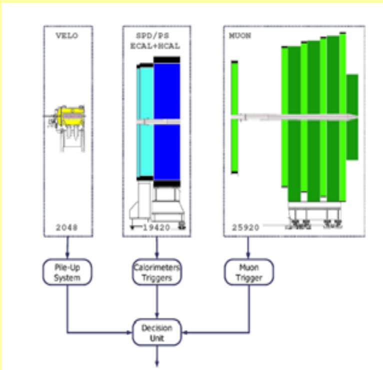
With full shielding 10 times less !

Minimum bias in LHCb 16 MHz x 20 charged particles = 3.2×10^8 charged particles/s in acceptance

pp collisions dominate still dominate when other background components are taken into account: beam gas in LSS (x2 old), elastic beam gas in Arc on TCT (x4?), beam 2

But spikes will have an influence on Single Events Upset: how big and for how long?

Trigger and background



L0 trigger, 1MHz (hardware):

- p_T of μ, e, h, γ

- Global event quantities to reject events

Scintillator Pad Detector charged multiplicity

Calorimeter total Energy

number of primary pp interactions in VELO PileUp

Sensitive to MIB (μ) background

Very old estimates (2002) for beam gas in LSS on trigger (LHCb-2002-041, LHCb-2003-074)

Only L0μ trigger: few % of bandwidth MIB and few % loss in efficiency for cases when pp collisions togheter with MIB, beam2 contribution negligible, no shields in tunnel. If pressures x10, loss up to ~10%

Preliminary results for beam1/TCTs: only IR7 inefficiency! (K.Hennessey et al.)

With 3 x 10^6 p/s on TCT, small MIB contribution to bandwidth (3 kHz with installed shield), bigger effect when pp collisions overlap with MIB (few % of bandwidth), full shield reduces both contributions (L0 hadron trigger more affected)

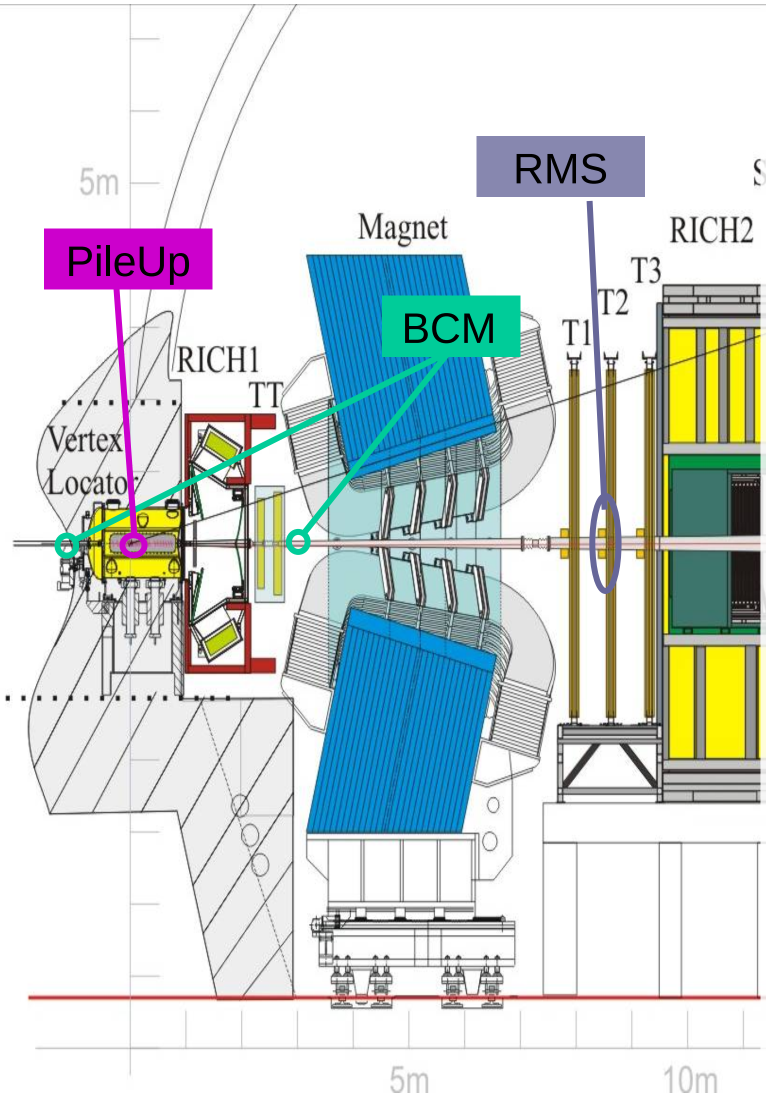
(sources from V.Talanov integrated in standard simulation)

HLT trigger (software):

- confirm L0, inclusive/exclusive selections

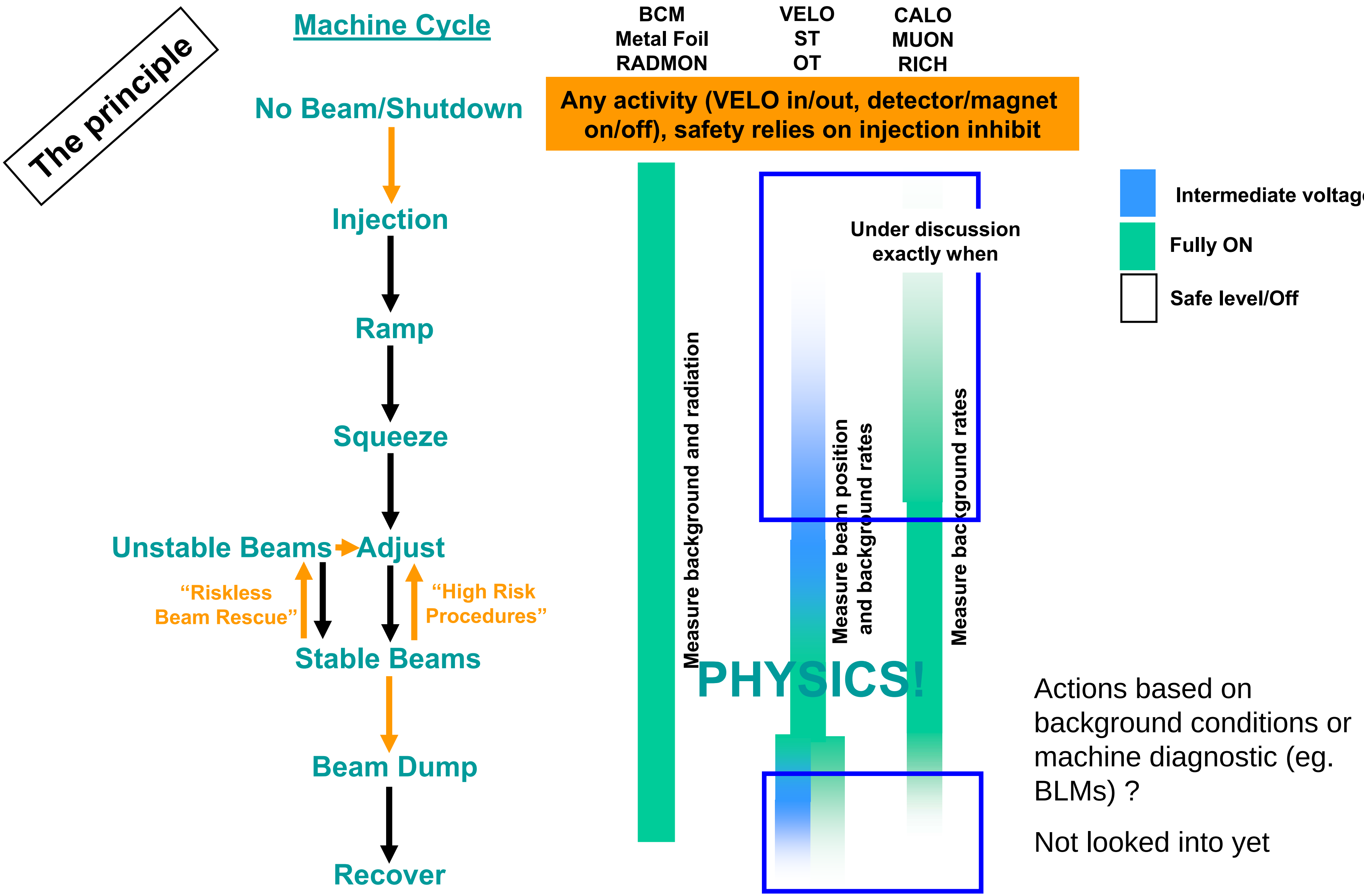
First phase could be affected by beam gas in VELO when happening with beam-beam collision, but rates expected to be very low (beam gas rates in whole VELO < 1 kHz with nominal beam)

How do we monitor conditions?



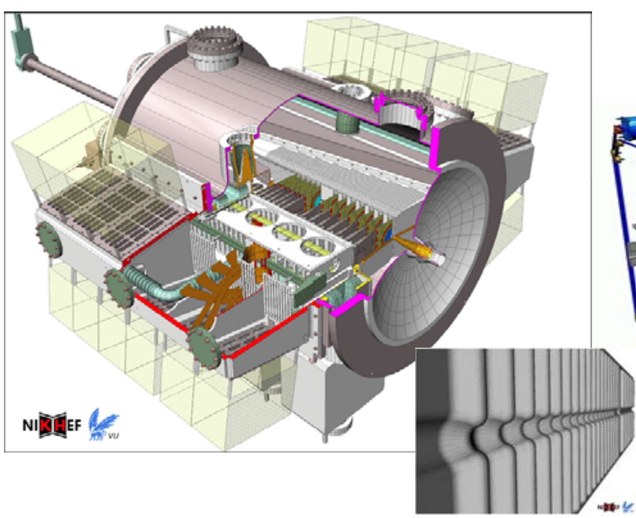
- <u>Slowly deteriorating conditions</u>
  - “BKG1 and BKG2” based on normalized levels from
    - Beam Condition Monitors
    - Metal Foil Radiation Monitorin System
    - Active Radiation Monitors ?
    - Detector Rates/Multiplicities, can be added when ON
  - Beam phase and intensity Monitor
  - Primary vertices multiplicity from PileUp system
  - Level gives “warning”
  - High level for long period causing excessive accumulated dose
    - Inform (insist on) LHC operators…
    - BKGx with sliding average/integrated dose?
    - LEP “Sliding integrated dose” was source of beam dump, now as well via HW/SW?
- <u>Risk of being brought to boiling point rapidly</u>
  - Beam Interlock System
    - Magnet failure
    - VELO at the wrong/right place at the right/wrong time
    - Machine failures as detected by BCM

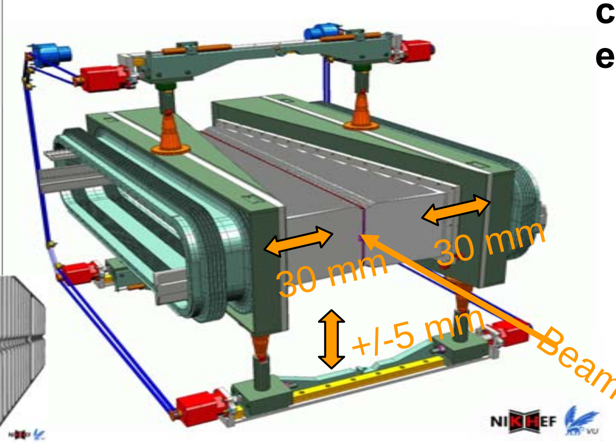
LHCb Operational Procedure



VErtexLOcator

- **VELO is a Movable Device:**
  - **Out position: 35mm from beam line**
  - **In nominal data taking position: 5mm from beam line**
  - **VELO can be close only with Stable Beams and Unstable Beams, or the other way around.**
  - **Data taking position determined with VELO open by profiling luminous region before moving in for every fill**
    - **May drive across nominal beam line**
    - **Very precise determination of luminous region**
      - **primary vertex known in x-y with ~50 μm/event precision with VELO open**





Very exposed to abnormal beam conditions (sensors and electronics)

Sensor tolerance 10^{12} MIPs/cm2/s→ O (100) less than loss of 10^{12} protons! Electronics tolerance 10^{8} MIPs/cm2/s!

Beam Condition Monitors

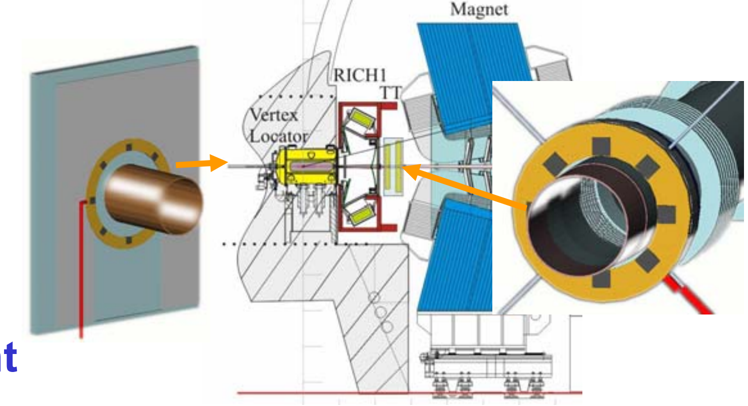
Based on CVD diamond detectors

- **Fast beam dump for unacceptable beam conditions (integration over 40 μs)**
  - Fast and slow dump thresholds
- **Real time background monitoring (longer integration time to see slow degradations or during injection)**
- **Especially important as independent assistant to VELO positioning**
  - Fast feedback needed if RF box scrapes beam halo
  - Signal in the diamonds becomes comparable with the minimum bias signal when the RF-foil separation is around 600 μm (or 6.8 σ for a beam sigma of 71 μm, nominal beam)
  - BCM OK signal to VELO positioning system
- **Investigating sensitivity in injection conditions**

MIB Rates in BCM and VELO: (Magnus Lieng)

5-10% of Minimum Bias signal strength with 3.0×10^6 p/s on TCT from IR7 and 1.2×10^7 p/s from elastic beam gas in Arcs

Eight single layer sensors located in a circle around the beam pipe before VELO and behind the TT

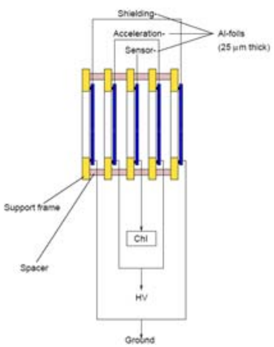


- Readout front-end same as BLMs
- Single receiver board for processing and logic for all sensors
- LHCb standard detector readout board (“TELL1”)
- Beam permit signals to CIBU
- Directly interfaced to the LHCb Experiment Control System (ECS) for readout and monitoring
- UPS

C.Ilgner et al. (Dortmund U.)

Metal Foil Radiation Monitoring System

RMS is based on Metal Foil Detectors (MFD)

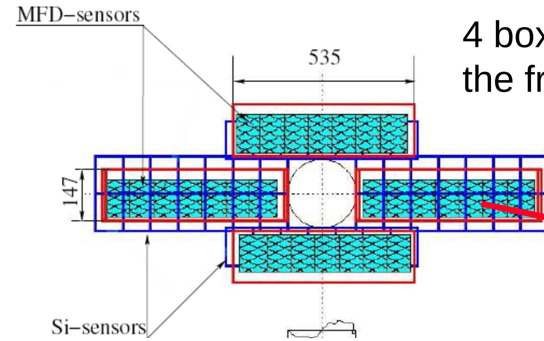


MDF 5-foils structure:

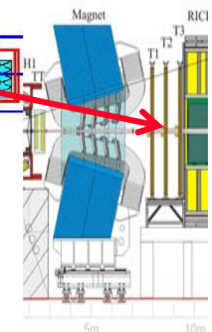
1 foil (middle) – sensor (connected to sensitive Charge Integrator, ChI)

2 foils (near sensor) – acceleration (connected to positive (HV) voltage).

2 foil (outer) – shielding (connected to ground)



4 boxes in a cross on the front side of IT2



Principle of operation – Secondary Electron Emission from metal foil surface (10-50 nm) caused by projectile charge particles

Positive charge created in metal foil is integrated by Charge Integrator - converted into a frequency, measured by a scaler

Interfaced to ECS for readout and monitoring

Main function: to monitor radiation load on Silicon Tracker sensors

Applying ASYMMETRY METHOD to the RMS (A_{UP}, A_{LR}) data one can provide monitoring:

charged particles induced background as well as relative luminosity of the LHCb experiment

interaction point position (in XY-plane only, similar method used in HERA-B)

Ideal for measuring charged particle fluxes exceeding $5 \times 10^3\ s^{-1}cm^{-2}$

V.Pugatch et al. (KINR)

To verify sensitivity at injection

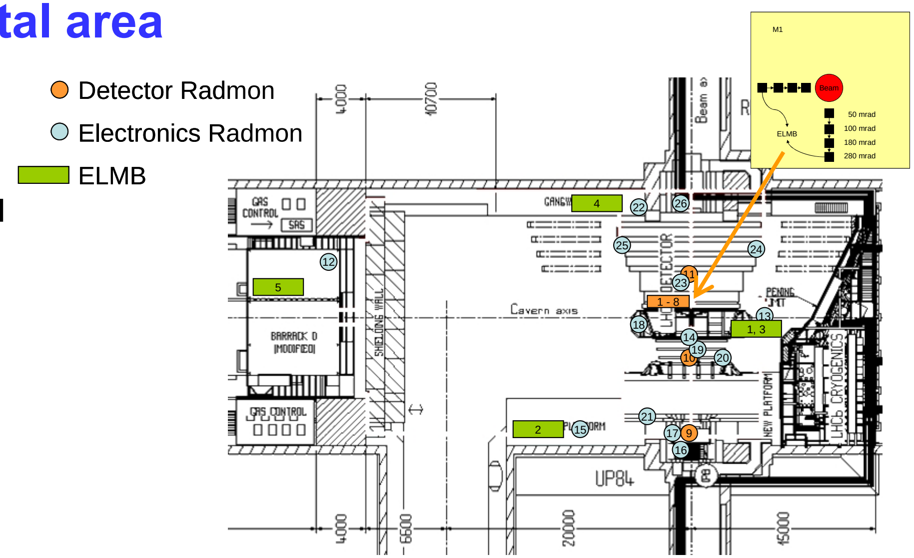
Active Radiation Monitors

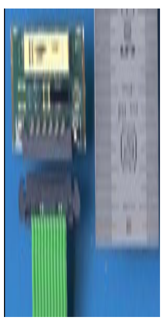
Monitor radiation levels in experimental area

Detector acceptance
- x-y cross section after RICH2
- 3 additional sensors along z at 320 mrad
- Hot position near beam pipe?

Electronics
- 14 sensors at major FE-electronic areas

Reference in D3 barrack





- Thin Oxide RadFET: 0.1 to 10 kGy
- Thick Oxide RadFET: 10^{-3} to 10 Gy
- High sensitive silicon diode 10^{8} to 2×10^{12} 1MeV n-eq/cm^2
- Particle detector diode 10^{11} to 5×10^{14} 1MeV n-eq/cm^2
- Temperature sensor

(developed by F.Ravotti and M.Glaser)
- ELMB readout

(developed by Ljubljana ATLAS group)

Provide levels at 1 Hz frequency

Feedback during run possible
Time correlation to electronics or detector performance possible
Compare with simulated radiation levels
Interfaced with ECS for readout and monitoring

Also passive radiation monitors in same location as active and RADMON from T.Wijnands in Cryogenic area + balcony and bunker

D.Wiedner et al (CERN)

Beams & luminous region

- **Beam phase and intensity measures bunch by bunch** R.Jacobsson (CERN)
  - **VME module developed by LHCb (BPIM) to read out the Button Electrode Beam Pick-ups located at 146m of IP8 (both sides)**
  - **Read out by ECS and fed to LHCb Timing and Fast Control**
- **Beam profile, luminous region and luminosity**
  - **Online reconstruction of pp interactions with VELO**
    - **must be done before closing VELO**
  - **Reconstruct beam gas interactions with VELO**
    - **get beam angles, profiles & relative positions**
    - **overlap integral**

Method to measure absolute luminosity with simultaneous measurement of bunch-bunch interaction vertices to calibrate ‘reference’ cross-section proposed by M.Ferro-Luzzi

Very low rate with residual gas pressure in IR → may need special trigger or/and to inject heavy gas

What diagnostic signals from LHC?

- **Need additional information to understand/disentangle sources of background**
  - **collimator positions**
  - **vacuum quality in IR8**

  and correlate to LHCb monitoring detectors
  - **Beam Loss Monitors**
  - **Beam Position Monitors**

    } close to IP8 (from MBXWS to collimators)
  - **BRANs (collision rates monitors)**

- **Are all available through DIP ?**

Few remaining questions

- LHCb Luminosity chosen to maximize number of single interactions/bunch crossing
  - Influence on occupancy: trigger and reconstruction
  - Ideally compensate beam lifetime by tuning β^*
  - How big bunch-to-bunch and fill-to-fill variation ?
- Satellite bunches
  - Extra luminous bumps at IP +/- n x 37.5 cm ? How big?
  - For n = +/- 1, still in VELO, should be able to observe it with normal tracking
  - For n > 1, like other interactions/decay in the detectors would require dedicated analysis, the same for n = -2
- LHCb detector « points » to IP8, displaced collisions outside of VELO are not as visible
- By construction in LHCb there will be non colliding bunches at IP (diplaced IR)
- Monitoring detectors (BCM, RMS) not sensitive to single bunches nor able to distinguish background from different beams in a simple way

Summary and Outlook

- Estimate contribution from all sources in a consistent manner
- LHCb trigger rates will be affected by background increases
- Spikes in background may also affect radiation levels (SEE)
- FULL shield will help in reducing impact of background !
- Need to understand how and when to combine various detectors information to provide BKGx signals for different machine modes
- How to normalize them will also be a learning process
- Necessary to combine information with machine diagnostic to understand the background sources