ATLAS and Beam Failures

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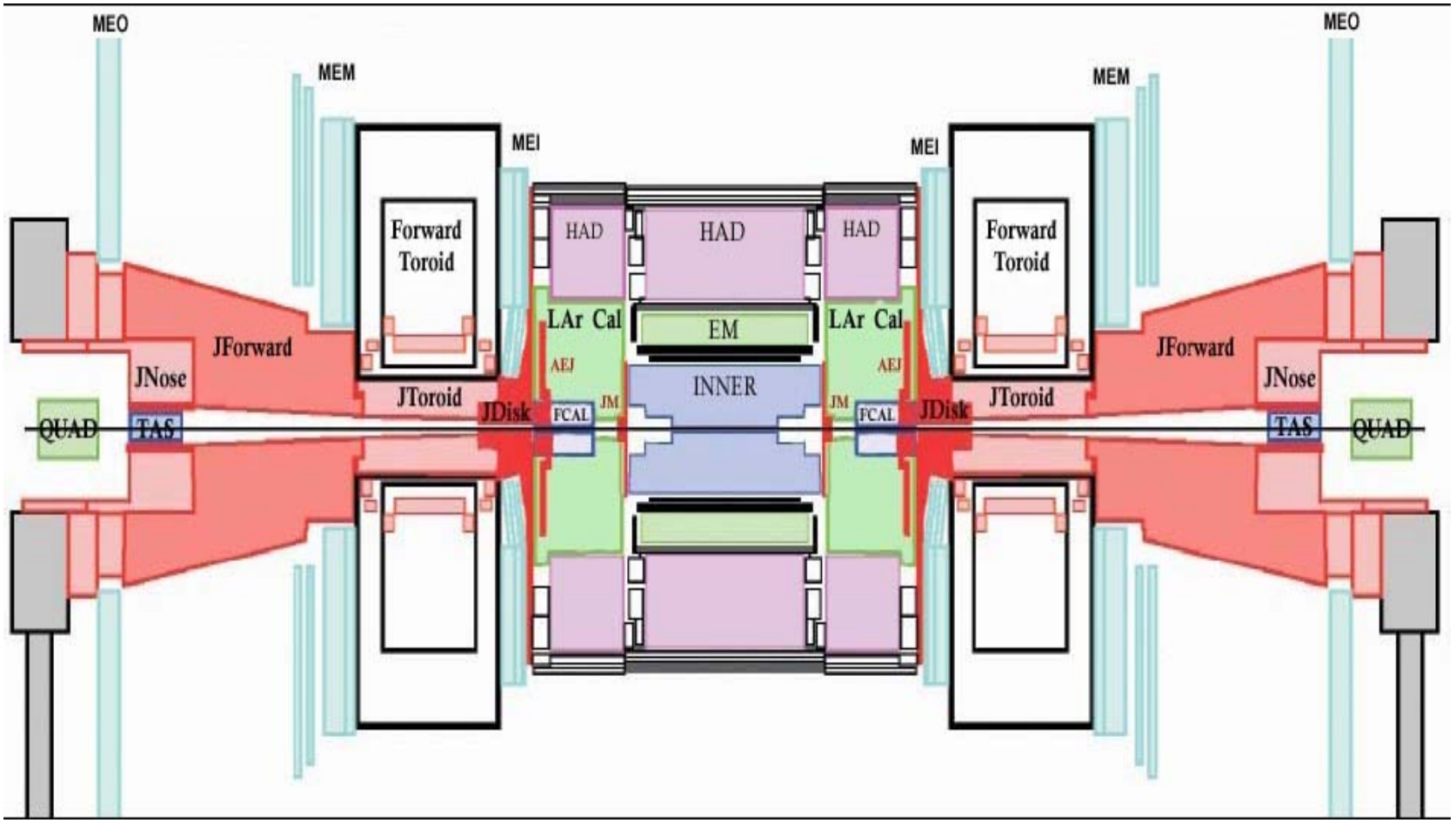
Workshop 12-06-07

Outline

- Beam loss at injection
- Loss of circulating beam
- ATLAS BIS
  - Logic
  - Hardware solution
  - Status

ATLAS Experiment



Beam Loss at Injection (1)

Studies based on

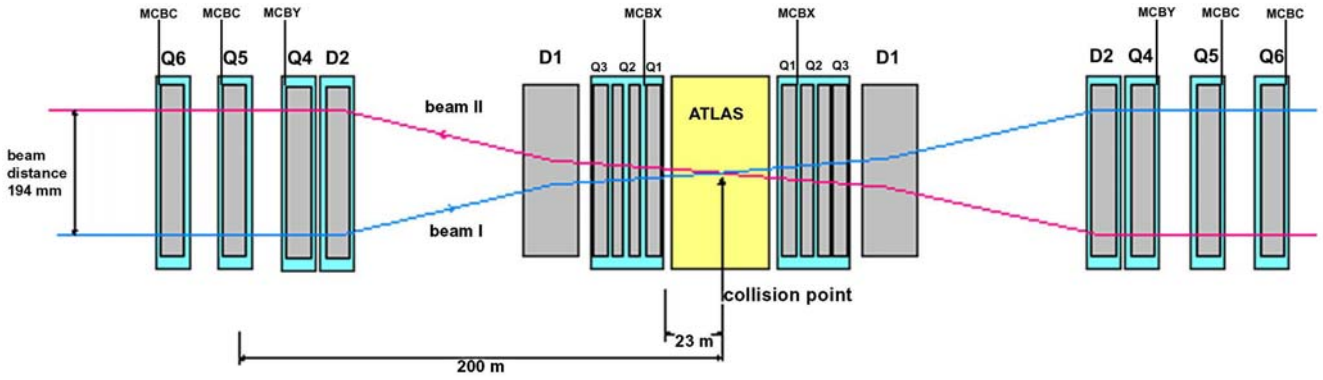
- Pilot bunch
  - Number of bunches: 1
  - Protons/bunch: 5×10^9
  - Proton momentum: 450 GeV/c
  - Bunch length (RMS): 11.2 cm
  - Beam size (RMS): 375 μm
  - Stored Energy: 360 J

- Certainly not on (safe beam) 10^{12} in empty machine

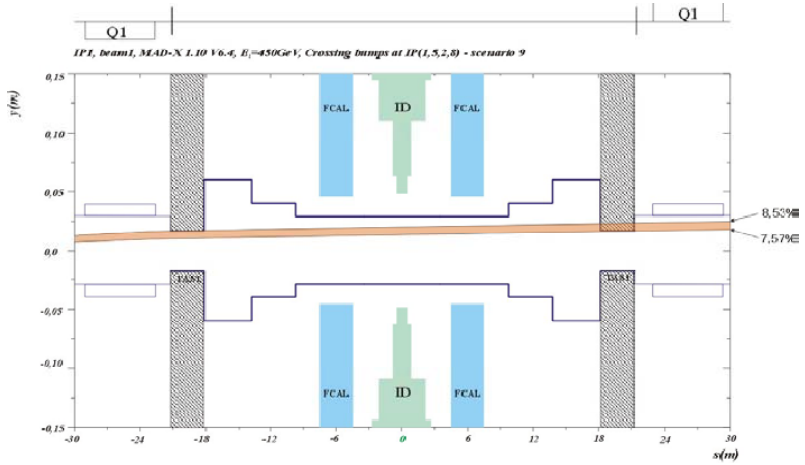
Beam Loss at Injection (2)

- LHC Project Note 335
  Accidental Beam Losses during Injection in the Interaction Region IR1
  Dariusz Bocian, January 2004

  – Various wrong settings of Magnets MCBXV, MCBXH, D1, D2
  – Most critical setting scenarios ?
    - Nominal setting only few percent of maximum strength
    - Wrong settings accordingly “small”
    - What if setting close to the one for 7 TeV/c ?

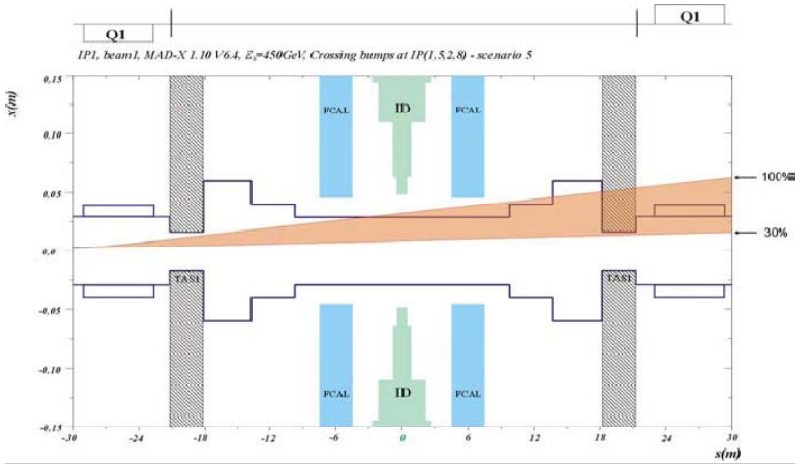


Beam Loss at Injection (3)



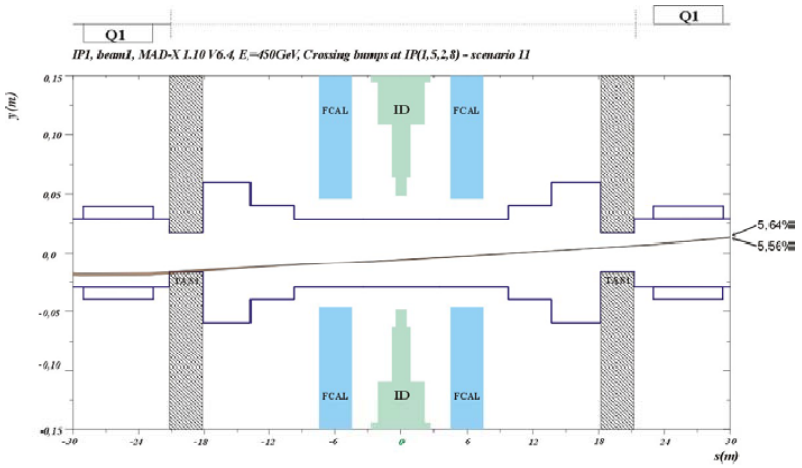
- Beam scrapes TAS towards IP (here: wrong setting of D1)
- Simulation of consequences for ATLAS detector
  - Muon system: o.k.
  - FCAL: o.k.
  - Pixel inner layer: 5×10^{-3} Gy ➔ C. Gemme et al, *NIM A565, 2006, 50*
- Beam scrapes TAS from IP ➔ 6.1×10^{6} J in Q1

Beam Loss at Injection (4)



- Beam hits beam pipe near Pixel Detector (wrong setting of MCBX)
- Simulation of consequences for ATLAS detector
  - Muon system: ?
  - FCAL: Factor 27 more
  - Pixel inner layer: Factor 42 more

Beam Loss at Injection (5)

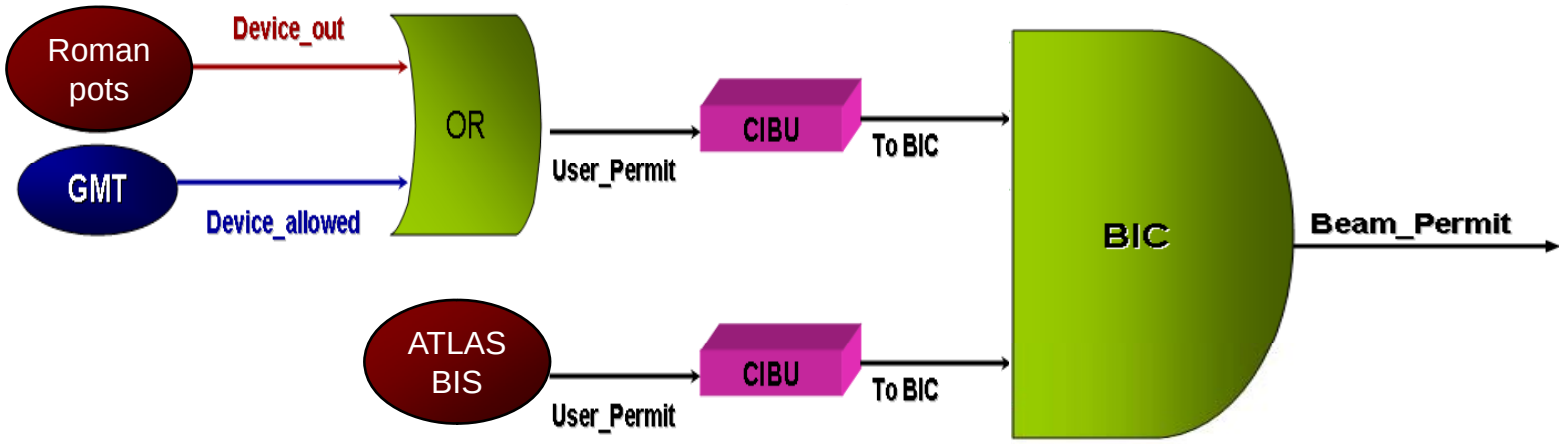


- Beam has large angle (wrong setting of D2)
  - 5.56% - 5.64% of max. strength (nominal 4.32%)
- What happens if field much higher (e.g. 7 TeV/c setting)?
  - Can beam bend into detectors ?
  - Or does it hit the TAS ?

Loss of Circulating Beam

- Machine protection should protect experiments
  - Collimation
  - Beam Loss Monitors
  - Long time constants in case of magnet failures
  - Also valid for safe beam mode ?
  - Where is last BLM ?
  - Can large bunch asymmetry lead to blow up at IP ?
  - How loss of vacuum close to IP is treated ?
- Nevertheless ATLAS will have beam interlock (part of LHC-BIS)
  - Protection of detector against eventual damage

ATLAS as User System

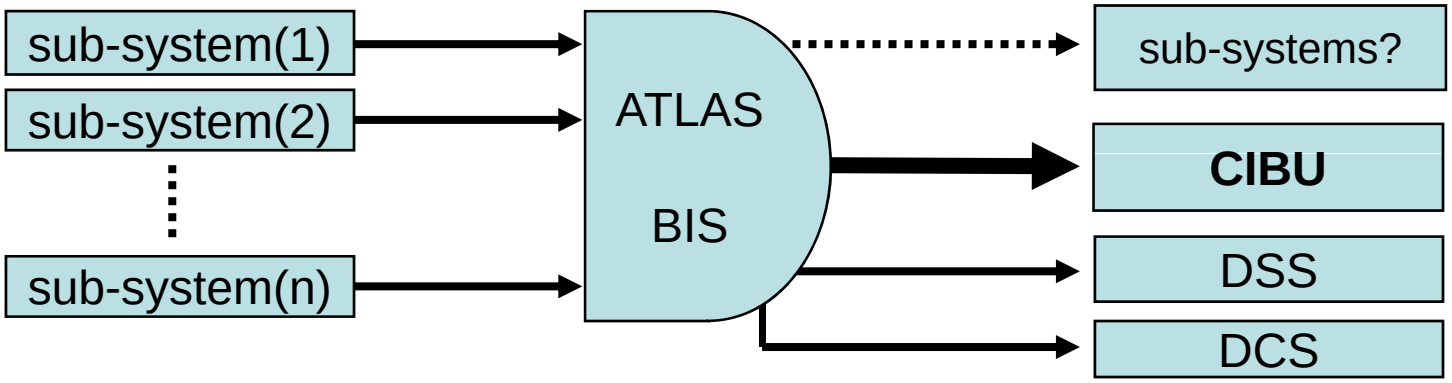


- CIBU-1 for ATLAS movable devices (Roman Pots)
- CIBU-2 for ATLAS sub-detectors

Realization of ATLAS-BIS

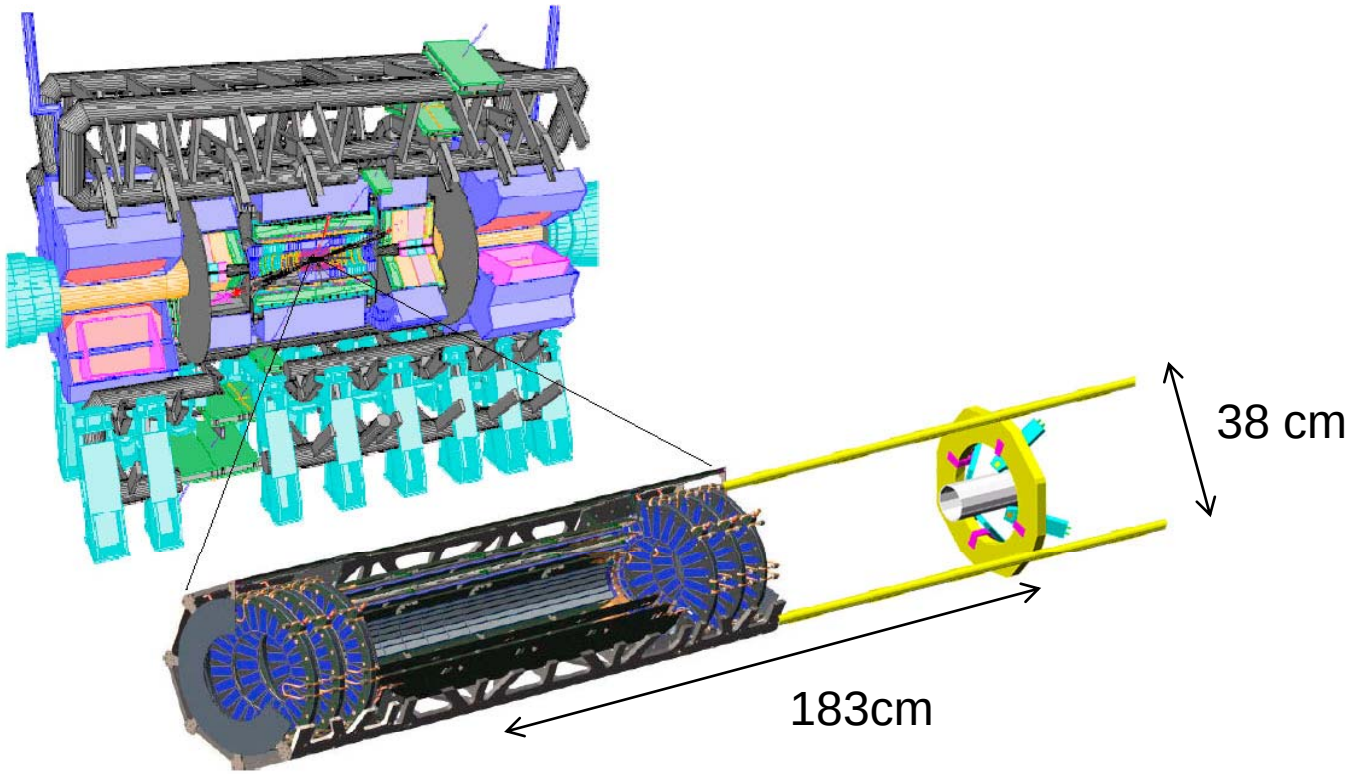
Follow logic of LHC-BIS

- Collect sub-system User_Permit signals
- Combinatorial logic creates ATLAS User_Permit for LHC-BIS
- If one sub-system User_Permit=False ➔ beam dump request
- If beam dump request sent
  - Inform sub-systems via DSS for safety actions (slow)
  - Inform DCS
  - Inform sub-systems directly, if fast action needed

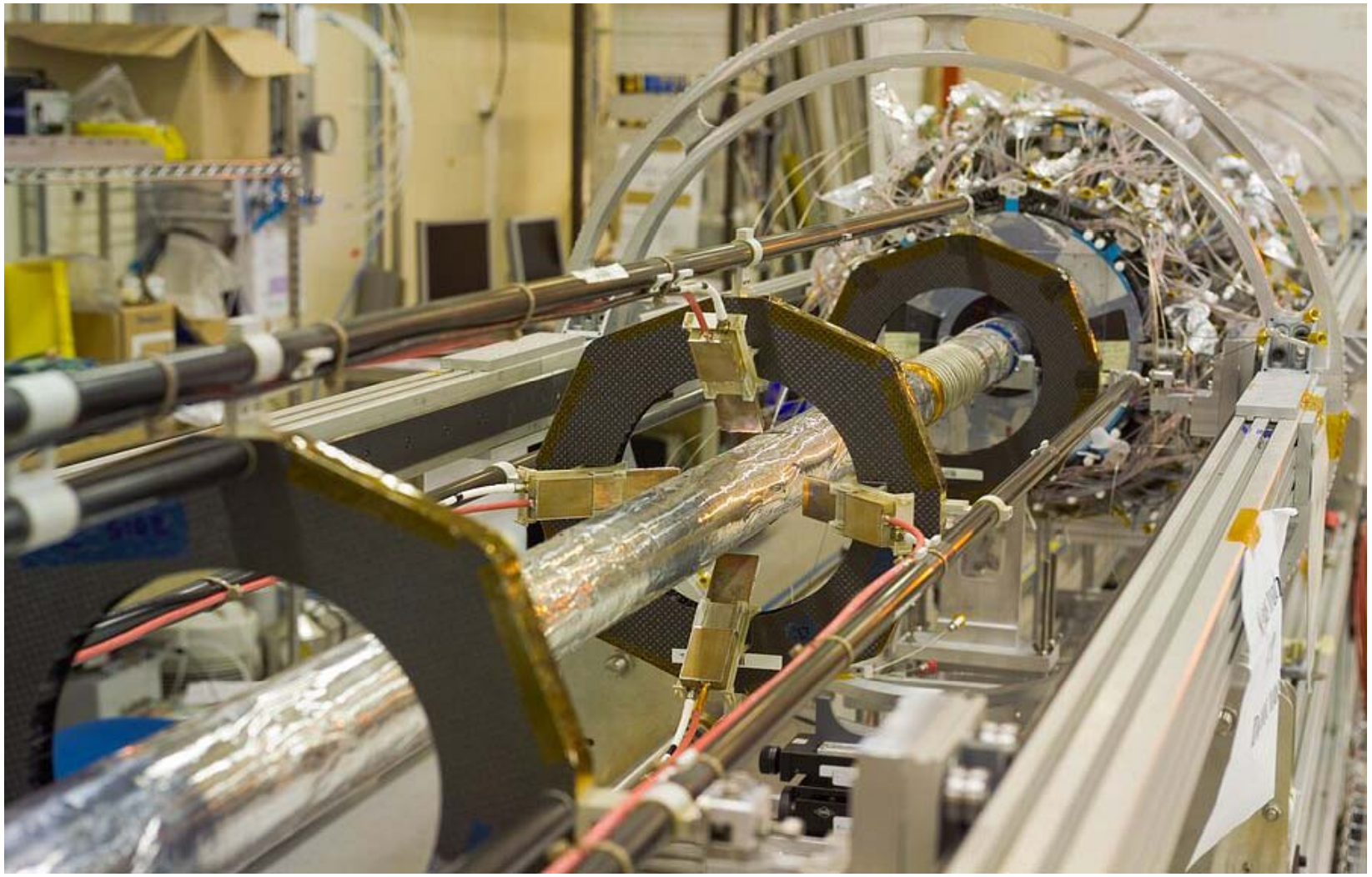


Sub-System(1) **BCM**

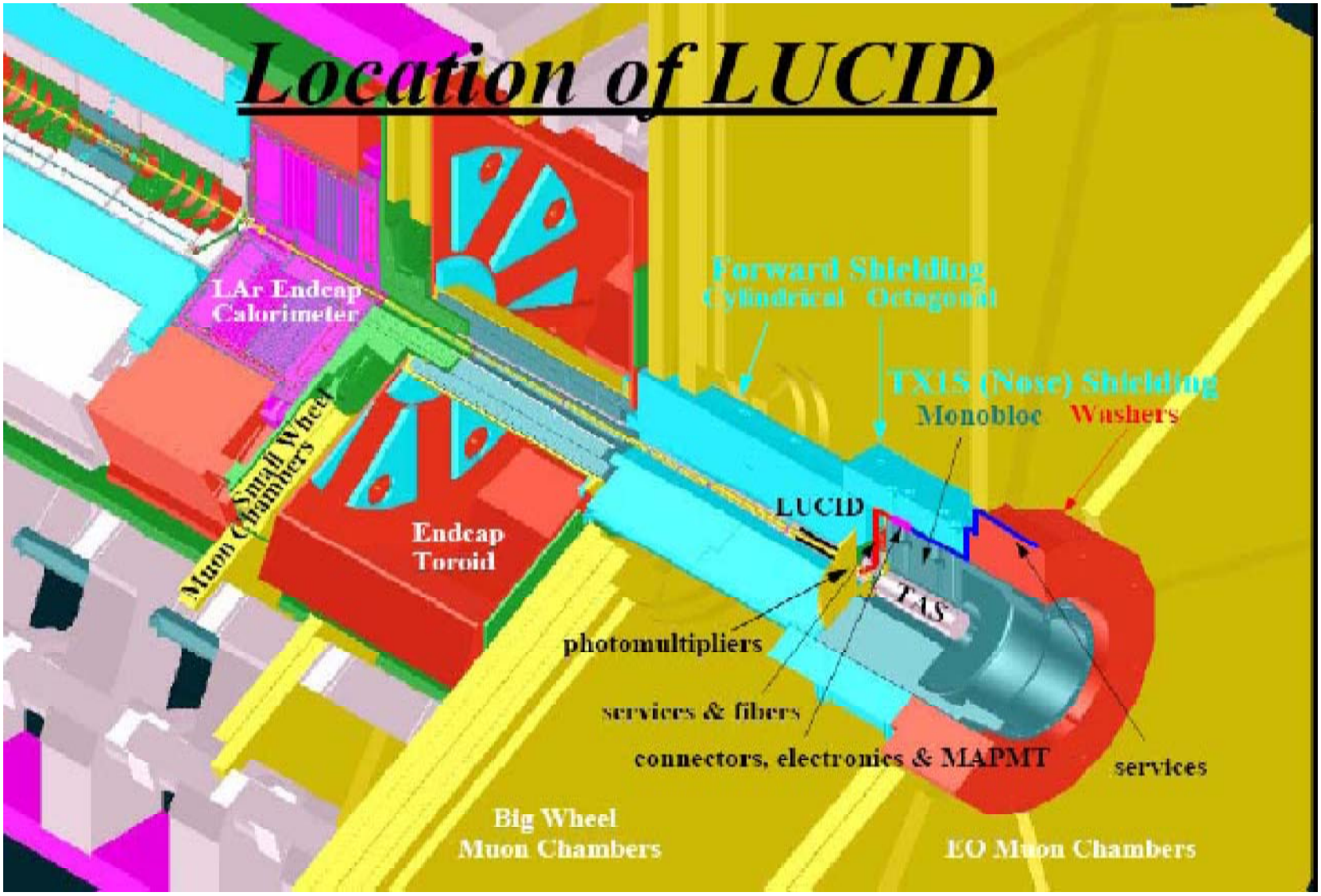
- 4 BCM stations on each side of the Pixel detector
  - Mounted on Pixel support structure at z = +/- 183.8 cm and r = 7 cm
  - Each station: 1cm^2 detector element + Front-end analog readout



ATLAS **B**eam **C**ondition **M**onitors



Sub-System(2) **LUCID**

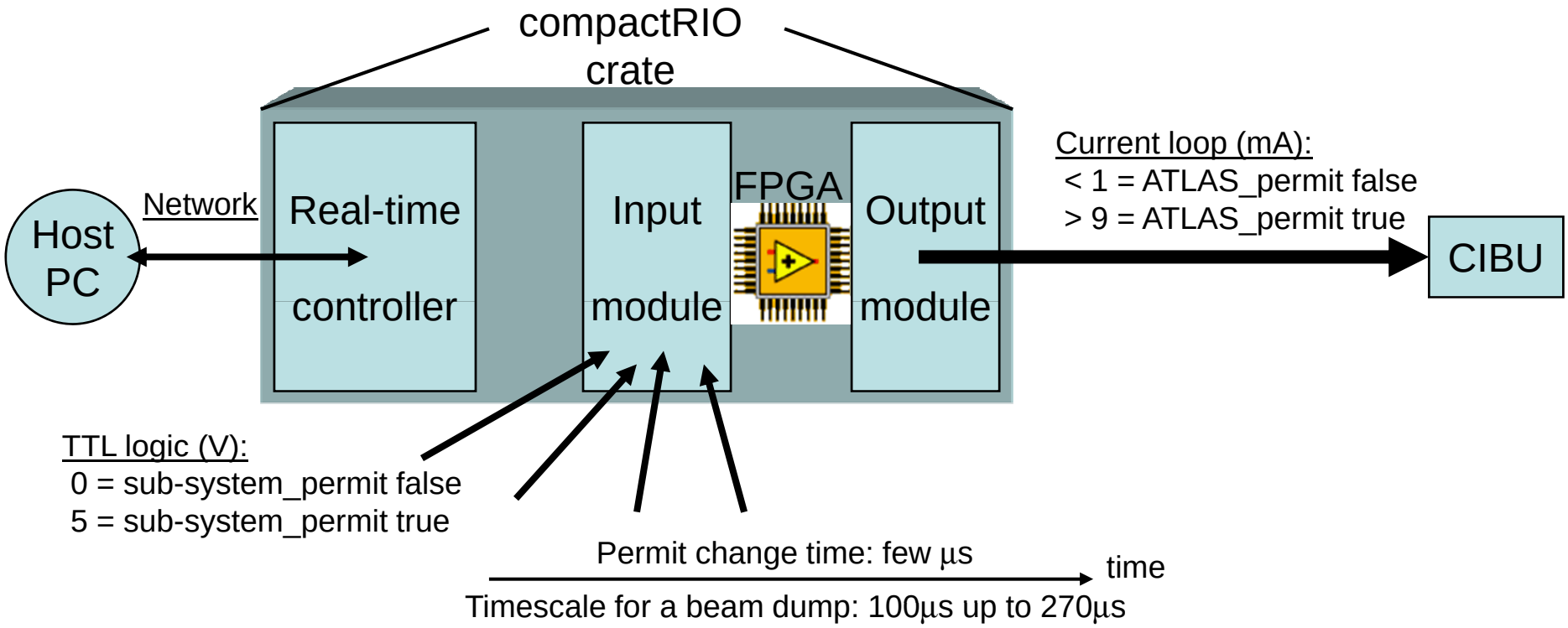


ATLAS-BIS SET-UP (1)

- Safety integrity level required leads to system based on hardware
- Studied 2 possibilities:
  - ASIC (application specific integrated circuit) chip not suitable:
    - Non-evolutive system (functionality defined at the very beginning)
    - Long development time
    - High cost
  - FPGA (Field Programmable Gate Array) well adapted:
    - Configured by programming the target (matrix of configurable-logic blocks surrounded by a periphery of I/O blocks)
    - Evolutive system with reconfigurable hardware after being put into service
    - Flexible and modular platform with a lot of different I/O modules

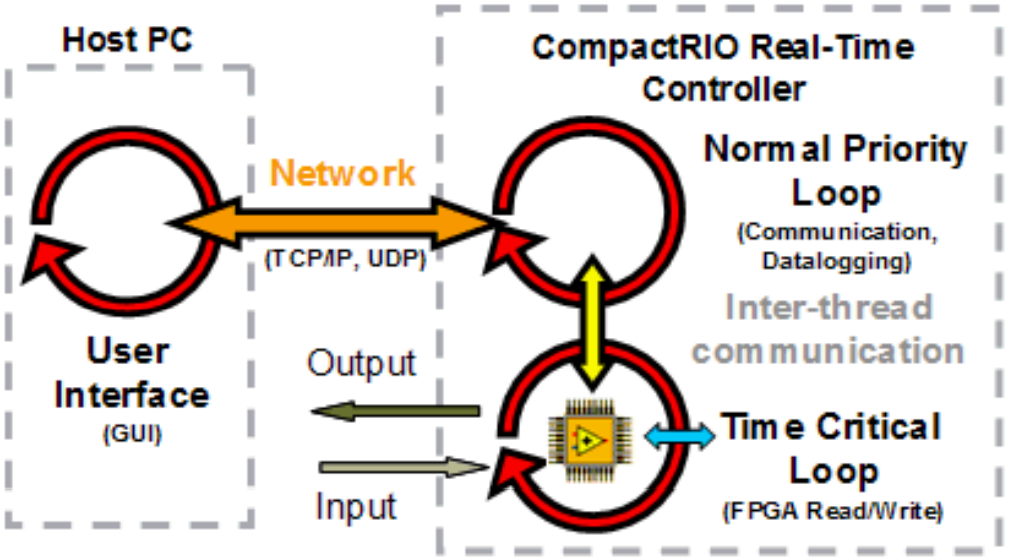
ATLAS-BIS SET-UP (2)

- Hardware interlock based on RIO technology
  - Custom hardware circuitry using reconfigurable FPGA chip
  - RIO core including FPGA chip + surrounding circuitry (I/O modules)
  - RIO core connected to a real-time controller



ATLAS-BIS SET-UP (3)

- Complete stand-alone embedded system
  - Critical logic and interlocks in silicon hardware circuitry: stand-alone, highest priority, non-interruptible loop
  - Data logging and ethernet communication performed by real-time controller: software loop to communicate with the FPGA
- External links and system monitoring
  - Link to DSS/DCS system via a dedicated output
  - Link to sub-systems via some specific channels if required
  - User interface on host PC via programmatic communication (TCP/IP)



Requirements of LHC-BIS for Experiments

- ✓ Send hardware signal (User_Permit) to CIBU
  - User-Permit = True ➔ Beam_Permit = True
  - User-Permit = False ➔ Beam dump request
  - User-Permit = False and no beam ➔ Injection inhibit
- ✓ Redundancy
  - 2 independent systems
  - 2 independent hardware signals
- ✓ Post-Mortem Analysis
  - Reason(s) for beam dump request will be available (for all ?)
- ✓ System will be operational and fully reliable well before first injection
  - Un-maskable on LHC side
- ✓ System will be on UPS
  - Even stand-alone UPS (as rack is shared)

Status

- Participating Sub-systems identified
  - BCM
  - LUCID
- Hardware solution found
- Hardware purchased and delivered
- Programming course taken
- Setting up and programming started
- Aim at
  - Having first test loop operational end of August
  - Having system fully operational end of 2007
  - Assuring possibility for extension and maintenance