Crystal collimation tests with heavy ion beams

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On behalf of the LHC Collimation team
• **Crystal collimation tests** carried out in **2015 and 2016 with Pb beam**, in **2017 with Xe beams**

• **Puzzling results obtained with Pb beams**

• After detailed analysis and exporting knowledge acquired also in the SPS, **improved collimator settings tested with Xe beams**

  Excellent results achieved and significant cleaning improvement demonstrated!

**Absorption of debris from TCSGs using TCLAs**

**Cleaning efficiency as a function of TCSG-TCLA**

**Improved cleaning performance in the range of 3-60 achieved with crystals!**
Proposed tests

- Fundamental requirement for all the discussion on possible operational use of crystals with Pb:
  - Reproduce good cleaning results obtained with Xe beam
  - Dedicated MD with low intensity needed

- If good results are achieved:
  - Possibility of End of Fill tests with high intensity
  - Possibility of operational tests along the entire cycle

- Possible collimation scheme for operational tests:
  - Adiabatic insertion of crystals in the collimation hierarchy

Operational system in place at nominal settings and crystals set as primary stage with 0.2-0.5σ tighter settings than TCPs

Cleaning performance of the system defined by the crystals while machine protection aspects fulfilled by presence of standard system at nominal settings
Configurations and validation required

- **When do we insert the crystals if operational tests allowed:**
  - Analysis of *loss spikes and lifetime* drops show *ramp* and *squeeze* as most critical points
  - Crystal insertion from injection preferred
  - Insertion at top energy would require a careful scraping/insertion with 5μm steps

- **Validation steps required** to allow End of Fill test and/or operational tests:
  - Test with *intermediate intensity* during the *intensity ramp up*
  - System performance *validation through standard loss maps procedure*

- **Number of fills required for validation dictated by ASD requirements:**
  - If only End of Fill tests allowed, 1 ASD with colliding beams would be sufficient
  - If tests during entire cycle foreseen, 3 ASD (flat top, end of squeeze, colliding)

- **Possible strategy for *timing/fill optimization***:
  1. Dedicated *MD with low intensity* early in the run, *early commissioning*?
  2. 1-2 days needed for detailed *off-line analysis*
  3. **Results will define the validation LM needed** and possible further tests (EoF or operational)
OP and MP aspects

• What will be needed from **OP side** in case of operational tests?
  ✓ Additional fields in LSA to load crystal position and angle functions
  ✓ Operational sequence
  ✓ Something else? (Belen’s talk)

• What will be needed from **MP side**?
  ✓ Present interlock strategy: beam permit is false if replacement beam pipe is out (maskable in SIS) or position limits are hit
    ➢ Present interlocks should be sufficient if only tests in static conditions are allowed
    ➢ Modifications needed if operational tests performed
  ✓ Present position limits stored in NON_MULTIPLEXED BP: discrete limit
    ➢ Impossible to implement function limits now
    ➢ Possible solution: two BP with discrete limits for injection and top energy
      • Limits changed loading BP through sequencer
      • Still possible drawback: crystals can still get to the flat top limits during the ramp
  ✓ Something else? (Daniel’s talk)
Gonio and Crystal aspects

• **Main requirement for the goniometers:**
  
  ✓ **Closed loop!**
  - 100% availability during high beta physics run
  - However, heavy ions run of about 1 month while high beta only 3 days...
  - More on goniometers performance in Mark’s talk

  ✓ **What if the closed loop is lost?**
  - If lost in static condition: slow drift of the crystal angle
    ✓ Channeling condition slowly lost
  - If lost in dynamic condition: fast drift of the crystal angle
    ✓ Channeling condition immediately lost

  ✓ **Any possibility to interlock on loop status?**
  - If not, lost of channeling condition immediately seen on the loss pattern.
    BLM based interlock?

• **Crystal robustness:**
  
  ✓ Do crystals get damaged if impacted during ASD?
  - HiRadMat tests and simulations performed (Marco’s talk)
BACKUP
Collimator settings

• From N. Fuster at HI2018 preparation meeting 5

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• Settings during crystal collimation tests:
  ✓ IR7 collimator upstream crystals opened
  ✓ IR7-TCSGs and TCLAs downstream crystals at settings in slide 2
  ✓ Rest of the system at nominal settings

• Settings during operational tests:
  ✓ All the system at nominal settings with crystals 0.2-0.5σ tighter than IR7-TCPs