WP13: BSRT modifications for HL-LHC

E. Bravin CERN BE-BI
24 February 2020
• Synchrotron radiation is emitted by charged particles when the trajectory of the particles is deflected (ex. Inside bending magnets)

• Special magnets (undulators), which force an harmonic oscillation of the particles, can be used to stimulate the emission of synchrotron radiation

• In the LHC a short undulator is used at injection energy since the radiation from the bending dipole is not sufficient
Principle of the BSRT

- Lens 1: f = 4m
- Lens 2: f = 250cm
Principle of the BSRT

Lens 1
f = 4m

Lens 2
f = 250cm

ND Filters
Principle of the BSRT

- **Lens 1**: f = 4m
- **Lens 2**: f = 250cm
- **ND Filters**
- **Color Filters**

Diagram showing an extraction mirror, dipole D3, undulator, and beam with labeled lenses and filters.
Principle of the BSRT

Lens 1
f = 4m

Lens 2
f = 250cm

ND Filters

Color Filters

Gated Intensified Camera

extraction mirror
dipole D3
undulator

beam
Principle of the BSRT

- Lens 1: $f = 4m$
- Lens 2: $f = 250cm$
- ND Filters
- Color Filters
- Gated Intensified Camera
Principle of the BSRT

- Lens 1: $f = 4\text{m}$
- Lens 2: $f = 25\text{cm}$
- ND Filters
- Color Filters
- Gated, Intensified Camera
Principle of the BSRT

- Lens 1: \( f = 4 \text{m} \)
- Lens 2: \( f = 250 \text{cm} \)
- ND Filters
- Color Filters
- Gated Intensified Camera

Diagram:
- Extraction mirror
- Dipole D3
- Undulator
- Beam
- Lens
- Gated Intensified Camera
Principle of the BSRT

Lens 1: f = 4 m

Lens 2: f = 250 cm

ND Filters

Color Filters

Gated Intensified Camera

Beam size

Lens: f = 25 cm
Principle of the BSRT

Lens 1
\( f = 4 \text{m} \)

Lens 2
\( f = 250 \text{cm} \)

ND Filters

Color Filters

Gated Intensified Camera

Beam Emittance

Beam size

Beam Emittance
Present BSRT

• **Beam 1** and **Beam 2**
  
  • BSRT: Refracting imaging telescope for online emittance measurement (limited by diffraction)
  
  • BSRA: Abort gap monitor
  
  • BSRL: Longitudinal density monitor (high dynamic range longitudinal profile with 50ps resolution)
  
• **Beam 1**
  
  • Double slit interferometer R&D (absolute beam size measurement not limited by diffraction)
  
  • Scanning slit with PMT (alternative to II+camera) ???
  
• **Beam 2**
  
  • Coronagraph for the measurement of the beam halo (HL-LHC R&D)
Principle of the BSRT

- Lens 1: $f = 4m$
- Lens 2: $f = 250cm$
- ND Filters
- Color Filters
- Gated Intensified Camera
Principle of the BSRT

Light splitter

Lens 1
f = 4m

Lens 2
f = 250cm

dipole D3

undulator

ND Filters

Color Filters

Gated Intensified Camera

BSRL

BSRA
Principle of the BSRT

- Lens 1: f = 4m
- Lens 2: f = 250cm
- ND Filters
- Color Filters
- Gated Intensified Camera
- Light splitter
- Spitter/switch
- To interferometer or coronagraph
- BSRL
- BSRA
- Dipole D3
- Undulator
LHC BSRT layout
LHC BSRT layout
LHC BSRT layout
HL-LHC BSRT

- **Beam 1** and **Beam 2**
  - BSRT: *Reflecting* imaging telescope for online emittance measurement (limited by diffraction) (compact version)
  - Double slit interferometer (simplified version)
  - Slit scanner for fast BbyB emittance measurement
    - Could help overcome limitation of image intensifier lifetime
  - Pin-hole camera using soft X-rays from undulator (High E) (option being investigated)
  - BSRA: Abort gap monitor
  - BSRL: Longitudinal density monitor (high dynamic range longitudinal profile with 50ps resolution)
    - Coronagraph for the measurement of the beam halo
    - Streak camera for the measurement of the crabbing
      - Clear specifications pending!
HL-LHC BSRT

- Beam 1 and Beam 2

- BSRT: *Reflecting* imaging telescope for online emittance measurement (limited by diffraction) (compact version)

- Double slit interferometer (simplified version)

- Slit scanner for fast BbyB emittance measurement
  - Could help overcome limitation of image intensifier lifetime

- Pin-hole camera using soft X-rays from undulator (High E) (option being investigated)

- BSRA: Abort gap monitor

- BSRL: Longitudinal density monitor (high dynamic range longitudinal profile with 50ps resolution)
  - Coronagraph for the measurement of the beam halo
  - Streak camera for the measurement of the crabbing
  - Clear specifications pending!

To many things to fit on one light source
Changes in BSRT for HL-LHC
Changes in BSRT for HL-LHC

CONSTRUCTION OF A NEW OPTICAL LIGHT EXTRACTION SYSTEM
FOR SYNCHROTRON LIGHT DIAGNOSTICS IN LSS4 WITH AN
ASSOCIATED OPTICAL LIGHT PATH AND OPTICAL HUTCH

[LHC-BSR]

WP13

Equipment/system description

This specification concerns the construction of a new light extraction system for synchrotron light diagnostics in HL-LHC. Synchrotron light from the D4 magnet will be extracted with an in-vacuum mirror located between D4 and D3 on each incoming beam to the left and right of Point 4. The extracted light will be sent via an optical light path from the tunnel to the respective UA in LSS4, where it will be used in a purpose built optical hutch.

<table>
<thead>
<tr>
<th>Layout Versions</th>
<th>LHC sectors concerned</th>
<th>CDD Drawings root names (drawing storage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>LSS4</td>
<td>LHC BSR</td>
</tr>
</tbody>
</table>

TRACEABILITY

<table>
<thead>
<tr>
<th>Project Engineer in charge of the equipment</th>
<th>WP Leader in charge of the equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Brawn</td>
<td>R. Jones</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Committee/Verification Role</th>
<th>Decision</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLC-HELTC/Performance and technical parameters</td>
<td>Rejected/Accepted</td>
<td>2014-07-08</td>
</tr>
<tr>
<td>Configuration-Integration / Configuration, installation and interface parameters</td>
<td>Rejected/Accepted</td>
<td>20YY-MM-DD</td>
</tr>
<tr>
<td>TC / Cost and schedule</td>
<td>Rejected/Accepted</td>
<td>20YY-MM-DD</td>
</tr>
</tbody>
</table>

Final decision by PL
Rejected/Accepted/Accepted pending (Integration studies, ...) 20YY-MM-DD

Distribution: HL-TC

Rev. No. | Date   | Description of Changes (major changes only, minor changes in EDMS)
---------|--------|--------------------------------------------------
1.0      | 2014-06-06 | Creation Date
Changes in BSRT for HL-LHC

CONTRUCTION OF A NEW OPTICAL LIGHT EXTRACTION SYSTEM FOR SYNCHROTRON LIGHT DIAGNOSTICS IN LSS4 WITH AN ASSOCIATED OPTICAL LIGHT PATH AND OPTICAL HUTCH

[LHC-BSR]
WP13

Equipment/system description
This specification concerns the construction of a new light extraction system for synchrotron light diagnostics in HL-LHC. Synchrotron light from the D4 magnet will be extracted with an in-vacuum mirror located between D4 and D3 on each incoming beam to the left and right of Point 4. The extracted light will be sent via an optical light path from the tunnel to the respective UA in LSS4, where it will be used in a purpose built optical hutch.

Traceability

<table>
<thead>
<tr>
<th>Version</th>
<th>LHC sectors concerned</th>
<th>CDD Drawings root names (drawing storage):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>LSS4</td>
<td>LHC BSRR</td>
</tr>
</tbody>
</table>

Decision Date

<table>
<thead>
<tr>
<th>Committee/Verification Role</th>
<th>Decision</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLC-HELTC/Performance and technical parameters</td>
<td>Rejected/Accepted</td>
<td>2014-07-08</td>
</tr>
<tr>
<td>Configuration/Installation and interface parameters</td>
<td>Rejected/Accepted</td>
<td>20YY-MM-DD</td>
</tr>
<tr>
<td>TC/Cost and schedule</td>
<td>Rejected/Accepted</td>
<td>20YY-MM-DD</td>
</tr>
</tbody>
</table>

Final decision by PL
Rejected/Accepted/Accepted pending (Integration studies, ...)
20YY-MM-DD

Distribution: HL-TC

Rev. No. Date Description of Changes (major changes only, minor changes in EDMs)
1.0 2014-06-06 Creation Date
Synchrotron light in IP4 (L)
Synchrotron light in IP4 (L)
Synchrotron light in IP4 (L)

B1

194 mm

B2

~25 m

420 mm

~60 m

~44 m
Synchrotron light in IP4 (L)
Synchrotron light in IP4 (L)
Without an undulator the new source can only be used for beam energies above 1.5 TeV.
New extraction tanks

- Learned a few things from present system
  - Alignment not super critical -> keep it simple!
  - Avoid viewport on the bottom (dust/dirt)
  - Adapt mirror position to beam energy (collimator like movement)
New extraction mirror design
New extraction mirror design
Design status

- Predesign (concept) done (E.B.)
- Impedance studies underway (B.S.)
  - So far no show stopper seen for the “basic” configuration, requested more detailed analysis with different positions of the mirror
- Mechanical design to start soon (involving ML)
- Plan to have one tank ready by end of 2021 or 2022
  - Install in YETS 22->23 at latest
SR spectrum in dipole magnet

- At 6.5 TeV we use 250 nm (near $\omega_{\text{max}}$)
- At 450 GeV we use the full visible spectrum
  - Dipole radiation basically absent ($\sim 1000 \times \omega_{\text{cr}}$)
Undulator

- $\Theta_{\text{obs}} = 0$
- $\lambda \propto \lambda_u / \gamma^2$
- $P \propto \gamma^2$

- $\lambda_{\text{coh}} = \frac{\lambda_u}{2 \gamma^2} \left( 1 + \frac{K^2}{2} + \gamma^2 \Theta_{\text{obs}}^2 \right)$

- $K = \frac{e B_0 \lambda_u}{2 \pi m_0 c}$

- $P = \frac{\pi e^2 c \gamma^2}{\varepsilon_0 \lambda_u^2 N_u} \frac{K^2}{\left( 1 + K^2 / 2 \right)^2}$
Do we need (a) new undulator(s)?

- Do we need to ramp down the undulators?
  - Evidence at end of run 2 that the UV from the undulatory is damaging the extraction mirrors
  - Ramping the present undulators in every cycle never used operationally…
- Advantage of second undulator
  - Freedom to move instruments from one source to the other
  - Instrument of second source (BSRH for now) useable also at injection energy
Do we need the optical lines?

- Streak cameras still in base line
  - Phase advance not favourable for crab monitoring
  - Will be a difficult device to run continuously (wear like for image intensifiers)
- May be streak cameras can survive long enough inside the tunnel (with an adequate shielding)
- Worth testing this option in run 3 (space constrains in present setup)
- Optical line for the moment on hold (space reserved in integration layout).
Summary

- HL-LHC requirements require a new synchrotron light pick-out
- Outgoing radiation from D4 identified as best option
- New SR extraction tank needed (design started)
- Undulator on new synchrotron light source would give more freedom in distributing instruments between sources
- Second source without undulator can be used only for the BSRH (and R&D at high energy)