SMOG2 upgrade at LHCb

- **SMOG**: System for Measuring Overlap with Gas
- **SMOG2**: Storage Cell for the gas upstream of the nominal IP (z in [-500, -300] mm) and precisely calibrated Gas Feed System.
  - Gas density increased by up to two orders of magnitude —> much higher luminosity
  - More gas targets: H₂, D₂, He, N₂, O₂, Ne, Ar, Kr, Xe
- **pp** and SMOG2 separate luminous regions —> simultaneous pp-SMOG2 data-taking.
- $\sqrt{s_{\text{NN}}} = 69$-110 GeV between SPS & RHIC
- $-3.0 < y^* < 0$
- Access nPDF anti-shadowing region

![Diagram of LHCb experiment](image)
SMOG2 upgrade at LHCb

- SMOG: System for Measuring Overlap with Gas
- SMOG2: Storage Cell for the gas upstream of the nominal IP (z in [-500, -300] mm) and precisely calibrated Gas Feed System.
  - Gas density increased by up to two orders of magnitude —> much higher luminosity
  - More gas targets: H₂, D₂, He, N₂, O₂, Ne, Ar, Kr, Xe
- \( pp \) and SMOG2 separate luminous regions —> simultaneous \( pp \)-SMOG2 data-taking.
- \( s_{NN} = 69-110 \) GeV between SPS & RHIC
- \( -3.0 < y^* < 0 \)
- Access nPDF anti-shadowing region
Statistics in 1 year data taking

simultaneous \( pp \)-SMOG2 data-taking

<table>
<thead>
<tr>
<th>Storage cell assumptions</th>
<th>gas type</th>
<th>gas flow ( \text{s}^{-1} )</th>
<th>peak density ( \text{cm}^{-3} )</th>
<th>areal density ( \text{cm}^{-2} )</th>
<th>time per year ( \text{s} )</th>
<th>int. lum. ( \text{pb}^{-1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMOG2 SC</td>
<td>He</td>
<td>( 1.1 \times 10^{16} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 3 \times 10^3 )</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Ne</td>
<td>( 3.4 \times 10^{15} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 3 \times 10^3 )</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Ar</td>
<td>( 2.4 \times 10^{15} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 2.5 \times 10^6 )</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Kr</td>
<td>( 8.5 \times 10^{14} )</td>
<td>( 5 \times 10^{11} )</td>
<td>( 5 \times 10^{12} )</td>
<td>( 1.7 \times 10^6 )</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Xe</td>
<td>( 6.8 \times 10^{14} )</td>
<td>( 5 \times 10^{11} )</td>
<td>( 5 \times 10^{12} )</td>
<td>( 1.7 \times 10^6 )</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>H(_2)</td>
<td>( 1.1 \times 10^{16} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 5 \times 10^6 )</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>D(_2)</td>
<td>( 7.8 \times 10^{15} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 3 \times 10^5 )</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>O(_2)</td>
<td>( 2.7 \times 10^{15} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 3 \times 10^3 )</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>N(_2)</td>
<td>( 3.4 \times 10^{15} )</td>
<td>( 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 3 \times 10^3 )</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Int. Lumi.**

80\(\text{pb}\)

**Sys. error of \( J/\Psi \) xsection**

\~3\%

SMOG2 pAr @ 115 GeV

<table>
<thead>
<tr>
<th></th>
<th>yield</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( J/\Psi )</td>
<td></td>
<td>28 M</td>
<td></td>
</tr>
<tr>
<td>( D^0 )</td>
<td></td>
<td>280 M</td>
<td></td>
</tr>
<tr>
<td>( \Lambda_c )</td>
<td></td>
<td>2.8 M</td>
<td></td>
</tr>
<tr>
<td>( \Psi' )</td>
<td></td>
<td>280 k</td>
<td></td>
</tr>
<tr>
<td>( \Upsilon(1S) )</td>
<td></td>
<td>24 k</td>
<td></td>
</tr>
<tr>
<td>( DY \mu^+\mu^- )</td>
<td></td>
<td>24 k</td>
<td></td>
</tr>
</tbody>
</table>
Physics programs and future measurements

• **Fixed Target Mode: SMOG2**

• **Physics:**
  • Intrinsic heavy-quark
  • *p*-Gas collisions: nPDFs, gluon anti-shadowing at large $x$, cold nuclear matter effects
  • Pb-Gas collisions: QGP formation, rapidity scan at lower energy, quarkonium sequential suppression

• **Measurements:**
  • Anti-proton production
  • $\rho$ in Central Exclusive Production
  • $X(3872)/\psi(2S)$ ratio in $p$He, $p$Ar, $p$Xe…
  • $\psi(2S) / J/\psi$ ratio in $p$He, $p$Ar, $p$Xe…
  • Strangeness production in $p$He, $p$Ar, $p$Xe…
  • $\Lambda_c^+ / D^0$ ratio in $p$He, $p$Ar, $p$Xe…
  • Drell-Yan

• **Collider Mode**
  • O-O collisions: do not expect centrality limitation. Simultaneous with SMOG2?
  • *p*-O collisions: study elemental composition of high energy cosmic rays
    • Help understand the forward particle flux in hadron-nucleus interactions at TeV scale
    • Help resolve the Muon Puzzle in the cosmic-ray induced air showers.

$\rho \psi(2S) \psi(1S) \Lambda_c^+ + c \Lambda_c^+ + c / D^0$

No centrality limitation!