A Fixed-Target ExpeRiment (AFTER) using the LHC beams

Cynthia Hadjidakis

Les Houches, January 17th 2014

- Physics opportunities with a fixed target experiments using the LHC proton and ion beams
- Expected luminosities
- Quarkonium case: yields and first studies
Physics opportunities of A Fixed-Target ExpeRiment (AFTER) @LHC

- Idea: use LHC beams on fixed target
  - 7 TeV proton beam ($\sqrt{s} \sim 115$ GeV)
  - p+H, p+A
  - 2.76 TeV Pb beam ($\sqrt{s_{NN}} \sim 72$ GeV)
  - Pb+A, Pb+H

- High boost and luminosity give access to the QCD at large $x = [0.3-1]$
  - Nucleon partonic structure
  - Spin physics
  - Nuclear shadowing
  - Quark Gluon Plasma
  - W/Z production near threshold
  - Other?

- Multi-purpose experiment

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Deep inelastic scattering (ep), Drell-Yan/Jet/Isolated photon/W/Z in hadronic collisions (pp): fixed-target or collider

High-$x$ pdfs: few data available (DIS) and mostly sensitive to valence-quarks

Sea and gluon pdfs at large $x$ extracted from DGLAP evolution equation → large uncertainty also for large scale
Proton structure: our current knowledge

Deep inelastic scattering (ep), Drell-Yan/Jet/Isolated photon/W/Z in hadronic collisions (pp): fixed-target or collider

High-\(x\) pdfs: few data available (DIS) and mostly sensitive to valence-quarks

Sea and gluon pdfs at large \(x\) extracted from DGLAP evolution equation → large uncertainty also for large scale

What about \(x = 0.3 - 1\) in proton, neutron and nuclear matter?
Gluon distribution function in the proton: very large uncertainty at large $x$
also at large $Q$
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Unknown for the neutron

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**Gluon distribution in the nucleon at large $x$**

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Gluon distribution in the nucleon at large $x$

Gluon distribution function in the proton: very large uncertainty at large $x$ also at large $Q$

Unknown for the neutron

- **Experimental probes @ AFTER**
  - Quarkonia
  - Isolated photons
  - High $p_T$ jets ($p_T > 20$ GeV/c)
    → to access target $x_g = 0.3 - 1$ (>1 Fermi motion in nucleus)

- **Target versatility**
  - Hydrogen
  - Deuteron (neutron)

Heavy-quark distribution at large $x$

Intrinsic charm motivated by non-perturbative models of hadron structure

All different charm pdfs (DGLAP or intrinsic charm) in agreement with DIS data


![Graphs of charm distributions](image)
Heavy-quark distribution at large $x$

Intrinsic charm motivated by non perturbative models of hadron structure

All different charm pdfs (DGLAP or intrinsic charm) in agreement with DIS data

- **Experimental probes @ AFTER**
  - Open charm (D meson or displaced-vertex lepton)
  - Open beauty

Boer-Mulders effect

Parton distribution functions pdfs \((x, Q^2) \rightarrow (x, k_T, Q^2)\): 3D or Transverse Momentum Dependent (TMD) pdfs

Boer-Mulders effect: correlation between the parton \(k_T\) and its spin (in an unpolarized nucleon)

Double-node structure of transverse-momentum distributions predicted for scalar and pseudoscalar quarkonia \(\rightarrow\) give access to the Boer-Mulders TMD pdf for gluons
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- **Experimental probes @ AFTER**
  - scalar and pseudoscalar quarkonia: \(\chi_c^0, \chi_b^0, \eta_c, \eta_b\) (PID and modern calorimetry)
Sivers effect in a transversely polarized nucleon: correlation between the parton $k_T$ and the proton spin.

Polarizing the target: measuring asymmetry to access the 3D or Transverse Momentum Dependent (TMD) pdfs.
Sivers effect with a transversally polarized target

Sivers effect in a transversally polarized nucleon: correlation between the parton $k_T$ and the proton spin

Polarizing the target: measuring asymmetry to access the 3D or Transverse Momentum Dependent (TMD) pdfs.

- **Experimental probes @ AFTER**
  - Drell-Yan → quark Sivers effect
  - Quarkonia, Open Charm and Beauty (B and D mesons), isolated $\gamma$ and $\gamma$-jet → gluon Sivers effect

- **Asymmetries > 5% predicted in Drell-Yan**
  for the target-rapidity region ($x_F = x_{\text{beam}} - x_{\text{target}} < 0$) where the $k_T$-spin correlation is the largest
Sivers effect with a transversely polarized target

Sivers effect in a **transversely polarized nucleon**: correlation between the **parton** $k_T$ and the **proton spin**

Polarizing the target: measuring asymmetry to access the 3D or Transverse Momentum Dependent (TMD) pdfs.

**Experimental probes @ AFTER**
- Drell-Yan $\rightarrow$ quark Sivers effect
- Quarkonia, Open Charm and Beauty (B and D mesons), isolated $\gamma$ and $\gamma$-jet $\rightarrow$ gluon Sivers effect

**Asymmetries $> 5\%$ predicted in Drell-Yan**
for the target-rapidity region ($x_F = x_{beam} - x_{target} < 0$) where the $k_T$-spin correlation is the largest

Gluon distribution in nucleus at large $x$

Large uncertainty in nuclei at large $x$

- **Experimental probes @ AFTER**
  - Quarkonia
  - Isolated photons
  - High $p_T$ jets ($p_T > 20$ GeV/c)
    → to access target $x_g = 0.3 - 1$ (>1 Fermi motion in nucleus)

- **Target versatility**
  - Probing the A-dependence of shadowing and nuclear matter effects
W, Z production in the threshold region

With high luminosity fixed-target experiment, W and Z production accessible

Unique opportunity to study the W and Z production near threshold @ AFTER

Very large x partons in the nucleon/nucleus target probed

Large NLO and NNLO corrections: QCD laboratory near threshold at large scale

If W’/Z’ exists, similar threshold corrections than W and Z
Quark Gluon Plasma

In nucleus-nucleus collisions at high ultra-relativistic energy → Quark Gluon Plasma (QGP) formation

RHIC energy scan shows suppression of particles at $\sqrt{s_{NN}} = 39, 62, 200$ GeV ($\pi^0$, $J/\Psi$, ...) but low statistics for $\sqrt{s_{NN}} < 200$ GeV and scarse / no pp and pA reference

Cold Nuclear Matter (i.e not Hot from QGP) measured in pA

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Cold Nuclear Matter (i.e not Hot from QGP) measured in pA

- Experimental probes @ AFTER $\sqrt{s} = 72$ GeV
  - Quarkonia
  - Jets
  - Low mass lepton pairs
  - ...

- Target versatility
  - In PbA, different nuclei: A-dependent studies
  - In pA, precise estimate of Cold Nuclear effects

Bottomonium family: five states, detection of the three $\Upsilon$ states separately (good resolution needed) to probe the bottomonium sequential suppression

See Jean-Philippe’s talk on friday
Y sequential melting in QGP

Bottomonium family: five states, detection of the three Y states separately (good resolution needed) to probe the bottomonium sequential suppression

See Jean-Philippe’s talk on friday
Luminosities in pH, pA, PbH and PbA
A possibility for proton and lead beam extraction at the LHC

E. Uggerhoj and U.I Uggerhoj NIMB 234 (2005) 34

Continuous extraction in the beam dump line

- Proposal for the insertion of a bent crystal in the LHC beam
  - Bent, single crystal of Si or Ge - 17cm long crystal
  - MKD kicker section at ~200 m from IP6
  - Deflection angle = 0.257 mrad (~7 T.m equivalent magnet)
  - Distance of 7σ to the beam to intercept and deflect the beam halo
  - No loss in the LHC beam
  - Bent crystal acts as a beam collimator

- Proton beam extraction
  - Single- or multi pass extraction efficiency of 50%
  - \( N_{\text{beam loss LHC}} \sim 10^9 \text{ p/s} \rightarrow N_{\text{extracted beam}} = 5 \times 10^8 \text{ p/s} \)
  - Extremely small emittance: beam size in the extraction direction) 950 m after the extraction ~ 0.3 mm

- Ion beam extraction
  - Ions extraction tested at SPS, is expected to be also possible at LHC but needs more study
  - May require bent diamonds (highly resistant to radiations)

See Andry's talk

P. Ballin et al, NIMB 267 (2009) 2952
Luminosities in pH and pA @ 115 GeV

• **Intensity**: $N_{\text{beam}} = 5.10^8 \text{ protons.s}^{-1}$
  - Beam: 2808 bunches of $1.15\times10^{11} \text{ p} = 3.2\times10^{14} \text{ p}$
  - Bunch: Each bunch passes IP at the rate: $\sim 11 \text{ kHz}$
  - Instantaneous extraction: IP sees $2808 \times 11000 \sim 3.10^7$ bunches passing every second $\rightarrow$ extract $\sim 16 \text{ protons}$ in each bunch at each pass
  - Integrated extraction: Over a 10h run: extract $\sim 5.6\%$ of the protons stored in the beam

• **Instantaneous Luminosity**
  $L = N_{\text{beam}} \times N_{\text{Target}} = N_{\text{beam}} \times (\rho \times e \times N_A)/A$
  - $N_{\text{beam}} = 5 \times 10^8 \text{ p}^+/\text{s}$
  - $e$ (target thickness) = 1 cm

• **Integrated luminosity**
  - 9 months running/year
  - 1 year $\sim 10^7 \text{ s}$

<table>
<thead>
<tr>
<th>Target (1 cm thick)</th>
<th>$\rho$ (g cm$^{-3}$)</th>
<th>A</th>
<th>$L$ (µb$^{-1}$ s$^{-1}$)</th>
<th>$\int L$ (pb$^{-1}$ yr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>solid H</td>
<td>0.088</td>
<td>1</td>
<td>26</td>
<td>260</td>
</tr>
<tr>
<td>liquid H</td>
<td>0.068</td>
<td>1</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>liquid D</td>
<td>0.16</td>
<td>2</td>
<td>24</td>
<td>240</td>
</tr>
<tr>
<td>Be</td>
<td>1.85</td>
<td>9</td>
<td>62</td>
<td>620</td>
</tr>
<tr>
<td>Cu</td>
<td>8.96</td>
<td>64</td>
<td>42</td>
<td>420</td>
</tr>
<tr>
<td>W</td>
<td>19.1</td>
<td>185</td>
<td>31</td>
<td>310</td>
</tr>
<tr>
<td>Pb</td>
<td>11.35</td>
<td>207</td>
<td>16</td>
<td>160</td>
</tr>
</tbody>
</table>

$\Rightarrow$ Large luminosity in pH(A) ranging from 0.1 and 0.6 fb$^{-1}$ for a 1 cm thick target
$\Rightarrow$ Larger luminosity with 50 cm or 1 m H2 or D2 target
Luminosities in PbA @ 72 GeV

- **Intensity:** $N_{beam} = 2.10^5 \text{ Pb.s}^{-1}$
  - Beam: 592 bunches of $7 \times 10^7$ ions = $4.1 \times 10^{10}$ ions
  - Bunch: Each bunch passes IP at the rate $\sim 11 \text{ kHz}$
  - Instantaneous extraction: IP sees $592 \times 11000 \sim 6.5 \times 10^6$ bunches passing every second $\rightarrow$ extract $\sim 0.03$ ions in each bunch at each pass
  - Integrated extraction: Over a 10h run: extract $\sim 15\%$ of the ions stored in the beam

- **Instantaneous Luminosity**
  $$L = N_{beam} \times N_{Target} = N_{beam} \times (\rho \times e \times N_A)/A$$
  - $N_{beam}=2 \times 10^5 \text{ Pb/s}$
  - $e$ (target thickness) = 1 cm

- **Integrated luminosity**
  - 1 months running/year
  - 1 year $\sim 10^6 \text{ s}$

⇒ AFTER provides a good luminosity to study QGP related measurements
Polarizing the hydrogen target

- **Instantaneous Luminosity**
  \[ L = N_{\text{beam}} \times N_{\text{Target}} = N_{\text{beam}} \times (\rho \times e \times N_A)/A \]
  - \(N_{\text{beam}} = 5 \times 10^8\) p/s
  - \(e\) (target thickness) = 50 cm

⇒ AFTER provides a **good luminosity to study target spin** related measurements

⇒ Complementary \(x_p^\uparrow\) range corresponds to Drell-Yan measurements

<table>
<thead>
<tr>
<th>Experiment</th>
<th>particles</th>
<th>energy (GeV)</th>
<th>(\sqrt{s}) (GeV)</th>
<th>(x_p^\uparrow)</th>
<th>(L) (nb⁻¹s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFTER</td>
<td>(p + p^\uparrow)</td>
<td>7000</td>
<td>115</td>
<td>0.01 (\pm) 0.9</td>
<td>1</td>
</tr>
<tr>
<td>COMPASS</td>
<td>(\pi^+ + p^\uparrow)</td>
<td>160</td>
<td>17.4</td>
<td>0.2 (\pm) 0.3</td>
<td>2</td>
</tr>
<tr>
<td>COMPASS</td>
<td>(\pi^+ + p^\uparrow)</td>
<td>160</td>
<td>17.4</td>
<td>~ 0.05</td>
<td>2</td>
</tr>
<tr>
<td>RHIC</td>
<td>(p^\uparrow + p)</td>
<td>collider</td>
<td>500</td>
<td>0.05 (\pm) 0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>J-PARC</td>
<td>(p^\uparrow + p)</td>
<td>50</td>
<td>10</td>
<td>0.5 (\pm) 0.9</td>
<td>1000</td>
</tr>
<tr>
<td>PANDA</td>
<td>(\bar{p} + p^\uparrow)</td>
<td>15</td>
<td>5.5</td>
<td>0.2 (\pm) 0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>PAX</td>
<td>(p^\uparrow + \bar{p})</td>
<td>collider</td>
<td>14</td>
<td>0.1 (\pm) 0.9</td>
<td>0.002</td>
</tr>
<tr>
<td>NICA</td>
<td>(p^\uparrow + p)</td>
<td>collider</td>
<td>20</td>
<td>0.1 (\pm) 0.8</td>
<td>0.001</td>
</tr>
<tr>
<td>RHIC</td>
<td>(p^\uparrow + p)</td>
<td>250</td>
<td>22</td>
<td>0.2 (\pm) 0.5</td>
<td>2</td>
</tr>
<tr>
<td>Int. Target 1</td>
<td>(p^\uparrow + p)</td>
<td>250</td>
<td>22</td>
<td>0.2 (\pm) 0.5</td>
<td>60</td>
</tr>
<tr>
<td>RHIC</td>
<td>(p^\uparrow + p)</td>
<td>250</td>
<td>22</td>
<td>0.2 (\pm) 0.5</td>
<td>60</td>
</tr>
</tbody>
</table>
Quarkonium case: annual yields
Quarkonium cross-sections at AFTER energy

Inclusive pp cross-sections

$B_{ll} \frac{d\sigma}{dy}|_{y=0}$ @ 115 GeV

$J/\psi = 20 \text{ nb}$

$\Upsilon = 40 \text{ pb}$

Inclusive pp cross-sections

$B_{ll} \frac{d\sigma}{dy}|_{y=0}$ @ 72 GeV

$J/\psi = 10 \text{ nb}$

$\Upsilon = 15 \text{ pb}$
In pp
⇒ RHIC @ 200 GeV x 100 with 10 cm thick H target
⇒ Comparable to LHCb if 1m H target
⇒ Detailed studies of quarkonium production (\(p_T\), y, polarization, different quarkonium states, ...)

In pA
⇒ RHIC @ 200 GeV x 100 with 1 cm Pb target
⇒ Detailed studies of cold nuclear matter effect in pA (\(p_T\), y, A, ...)

Geometrical Acceptance
Simulations using ALICE as a fixed target experiment at LHC quotes a Geometrical Acceptance of 8% for \(J/\psi\) (4 \(\pi\)) → \(\mu^+\mu^-\) (2.5 < y < 4) using the Forward Muon Spectrometer @ 115 GeV

\[ \begin{array}{|c|c|c|c|}
\hline
\text{Target} & \int dt\mathcal{L} & B_{\ell\ell}\frac{dN_{J/\psi}}{dy}_{y=0} & B_{\ell\ell}\frac{dN_{\pi}}{dy}_{y=0} \\
\hline
10 \text{ cm solid H} & 2.6 & 5.2 \times 10^7 & 1.0 \times 10^5 \\
10 \text{ cm liquid H} & 2 & 4.0 \times 10^7 & 8.0 \times 10^4 \\
10 \text{ cm liquid D} & 2.4 & 9.6 \times 10^7 & 1.9 \times 10^5 \\
1 \text{ cm Be} & 0.62 & 1.1 \times 10^8 & 2.2 \times 10^5 \\
1 \text{ cm Cu} & 0.42 & 5.3 \times 10^8 & 1.1 \times 10^6 \\
1 \text{ cm W} & 0.31 & 1.1 \times 10^9 & 2.3 \times 10^6 \\
1 \text{ cm Pb} & 0.16 & 6.7 \times 10^9 & 1.3 \times 10^6 \\
\hline
\end{array} \]

\[ \begin{array}{|c|c|c|c|}
\hline
\text{Luminosity per year in fb}^{-1} & \int dt\mathcal{L} & B_{\ell\ell}\frac{dN_{J/\psi}}{dy}_{y=0} & B_{\ell\ell}\frac{dN_{\pi}}{dy}_{y=0} \\
\hline
pp \text{ low } P_T \text{ LHC (14 TeV)} & 0.05 & 3.6 \times 10^7 & 1.8 \times 10^5 \\
pPb \text{ LHC (8.8 TeV)} & 10^{-4} & 1.4 \times 10^9 & 7.2 \times 10^6 \\
pp \text{ RHIC (200 GeV)} & 1.2 \times 10^{-2} & 4.8 \times 10^5 & 1.2 \times 10^3 \\
dAu \text{ RHIC (200 GeV)} & 1.5 \times 10^{-4} & 2.4 \times 10^6 & 5.9 \times 10^3 \\
dAu \text{ RHIC (62 GeV)} & 3.8 \times 10^{-6} & 1.2 \times 10^4 & 1.8 \times 10^1 \\
\hline
\end{array} \]

Quarkonium distributions in pp @ 115 GeV

**Pythia 6.4.21**: p (7 TeV) + p → J/ψ (isub=86)

\[ J/\Psi \rightarrow \mu^+\mu^- \]

μ from J/ψ for 1.3 < y_{lab} < 5.3

\( p_T \sim 1.7 \) GeV

\( p_L \sim 62 \) GeV

Longitudinal muon momentum

1.3 < y_{lab} < 3.3

\( p_L (\text{max}) \sim 16 \) (50) GeV

3.3 < y_{lab} < 4.3

\( p_L (\text{max}) \sim 45 \) (150) GeV

4.3 < y_{lab} < 5.3

\( p_L (\text{max}) \sim 120 \) (300) GeV
Accessing the large $x$ gluon pdf

**PYTHIA simulation**

$\sigma(y) / \sigma(y=0.4)$
statistics for one month
5% acceptance considered

**Statistical relative uncertainty**
Large statistics allow to access very backward region

**Gluon uncertainty from MSTWPDF**
- only for the gluon content of the target
- assuming

\[ x_g = \frac{M_{J/\Psi} / \sqrt{s}}{e^{-y_{CM}}} \]

**$J/\Psi$**

\[ y_{CM} \sim 0 \rightarrow x_g = 0.03 \]
\[ y_{CM} \sim -3.6 \rightarrow x_g = 1 \]

**$Y$: larger $x_g$ for same $y_{CM}$**

\[ y_{CM} \sim 0 \rightarrow x_g = 0.08 \]
\[ y_{CM} \sim -2.4 \rightarrow x_g = 1 \]

$\Rightarrow$ Backward measurements allow to access large $x$ gluon pdf

**Simulations needed!**
Quarkonium yields in PbA @ 72 GeV

PbA
⇒ Same statistics than RHIC @ 200 GeV and LHC and 2 orders of magnitude larger than RHIC @ 62 GeV
⇒ Detailed studies possible for quarkonium states ($\psi'$, $\chi_c$, A-dependence, ...)

<table>
<thead>
<tr>
<th>Target</th>
<th>$\int dt\mathcal{L}$</th>
<th>$B_{\text{ee}} \frac{dN_{J/\psi}}{dy}_{y=0}$</th>
<th>$B_{\text{ee}} \frac{dN_{\chi}}{dy}_{y=0}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 cm solid H</td>
<td>110</td>
<td>$4.3 \times 10^5$</td>
<td>$8.9 \times 10^2$</td>
</tr>
<tr>
<td>10 cm liquid H</td>
<td>83</td>
<td>$3.4 \times 10^5$</td>
<td>$6.9 \times 10^2$</td>
</tr>
<tr>
<td>10 cm liquid D</td>
<td>100</td>
<td>$8.0 \times 10^5$</td>
<td>$1.6 \times 10^3$</td>
</tr>
<tr>
<td>1 cm Be</td>
<td>25</td>
<td>$9.1 \times 10^5$</td>
<td>$1.9 \times 10^3$</td>
</tr>
<tr>
<td>1 cm Cu</td>
<td>17</td>
<td>$4.3 \times 10^6$</td>
<td>$0.9 \times 10^3$</td>
</tr>
<tr>
<td>1 cm W</td>
<td>13</td>
<td>$9.7 \times 10^6$</td>
<td>$1.9 \times 10^4$</td>
</tr>
<tr>
<td>1 cm Pb</td>
<td>7</td>
<td>$5.7 \times 10^6$</td>
<td>$1.1 \times 10^4$</td>
</tr>
<tr>
<td>dAu RHIC (200 GeV)</td>
<td>150</td>
<td>$2.4 \times 10^6$</td>
<td>$5.9 \times 10^3$</td>
</tr>
<tr>
<td>dAu RHIC (62 GeV)</td>
<td>3.8</td>
<td>$1.2 \times 10^4$</td>
<td>$1.8 \times 10^1$</td>
</tr>
<tr>
<td>AuAu RHIC (200 GeV)</td>
<td>2.8</td>
<td>$4.4 \times 10^6$</td>
<td>$1.1 \times 10^4$</td>
</tr>
<tr>
<td>AuAu RHIC (62 GeV)</td>
<td>0.13</td>
<td>$4.0 \times 10^4$</td>
<td>$6.1 \times 10^1$</td>
</tr>
<tr>
<td>$pPb$ LHC (8.8 TeV)</td>
<td>100</td>
<td>$1.0 \times 10^7$</td>
<td>$7.5 \times 10^4$</td>
</tr>
<tr>
<td>PbPb LHC (5.5 TeV)</td>
<td>0.5</td>
<td>$7.3 \times 10^6$</td>
<td>$3.6 \times 10^4$</td>
</tr>
</tbody>
</table>

Luminosity per year in fb$^{-1}$
Multiplicity in PbA

A highly granular detector is needed

<table>
<thead>
<tr>
<th>$y &lt; 0.5$</th>
<th>$R_{\text{min}}$ (cm)</th>
<th>$R_{\text{max}}$ (cm)</th>
<th>Surface (cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex</td>
<td>1.5</td>
<td>10</td>
<td>~300</td>
</tr>
<tr>
<td>Calo</td>
<td>10</td>
<td>40</td>
<td>~4700</td>
</tr>
</tbody>
</table>

$1\% \sim \frac{450}{300 \times \left( \frac{1}{0.8 \times 0.8 \text{ mm}^2} \right)} \sim 14\%$

$0.1\% \sim \frac{450}{300 \times \left( \frac{1}{0.25 \times 0.25 \text{ mm}^2} \right)} \sim 3.7\%$

Charged particles per unit of rapidity: (x 1.5 = charged+neutral)

$p+p @ 115 \text{ GeV} \sim 2$

$d+Au @ 200 \text{ GeV} : \text{max} \sim 11$

$Au+Au @ 62.4 \text{ GeV} : \text{max} \sim 450$
• LHC proton and lead beams continuous extraction with bent crystal offers many physics opportunities

• Large luminosities provide access to large and very large parton $x$ measurements for quarks and gluons: QCD laboratory at large $x$

• Fixed-target mode allows for target versatility: hydrogen, deuteron, nucleus (nuclear effect and QGP), polarized target (spin physics)

• AFTER designed as a multi-purpose experiment
M. Anselmino (Torino), R. Arnaldi (Torino), S.J. Brodsky (SLAC), V. Chambert (IPN), J.P. Didelez (IPN), B. Genolini (IPN), E.G. Ferreiro (USC), F. Fleuret (LLR), C. Hadjidakis (IPN), J.P Lansberg (IPN), C. Lorcé (IPN), A. Rakotozafindrabe (CEA), P. Rosier (IPN), I. Schienbein (LPSC), E. Scomparin (Torino), U.I. Uggerhøj (Aarhus)

Looking for partners!
Drell-Yan continuum

**Kinematical limit for Drell-Yan at 7 TeV on fixed target**

$$M \geq x_B \cdot \text{target}$$

$$x_B \text{ kinematical limit}$$

**backward region**

$$x_{\text{target}} = x_{\text{beam}}$$

**forward region**

$$x_{\text{beam}}$$

$$x_{\text{target}}$$
Tentative design for AFTER
Rapidity boost in a fixed target mode

- **Very high boost:**
  - With 7 TeV beam
    \[ \gamma = \sqrt{s/(2m_p)} = 61.1 \text{ and } y_{CMS} = 4.8 \]
  - With 2.76 TeV beam
    \[ \gamma = 38.3 \text{ and } y_{CMS} = 4.3 \]

- \( \eta_{CM} = \eta_{lab} - y_{CMS} \)
  - **forward region:** \( \eta_{CM}>0 \)
  - **backward region:** \( \eta_{CM}<0 \)

- \( \eta = - \ln \tan \theta/2 \)
  \[ \rightarrow \theta (y_{CM}=0) \approx 0.9^\circ \text{ (16 mrad)} \]
  - \( y_{lab}(J/\Psi) \approx 4.8 \rightarrow x_2(J/\Psi) = 0.03 \)
  - \( y_{lab}(\Upsilon) \approx 4.8 \rightarrow x_2(\Upsilon) = 0.08 \)

- **Taking** \( x_2 = M/\sqrt{s} \ e^{-y_{CM}} \)
  - \( x_2(J/\Psi) = 1 \rightarrow y_{lab}(J/\Psi) \approx 1.2 \)
  - \( x_2(\Upsilon) = 1 \rightarrow y_{lab}(\Upsilon) \approx 2.4 \)

- **Very well placed to access backward physics**
A tentative design for AFTER

- **Tentative design** $1.3 < y_{\text{lab}} < 5.3$
  - With 7 TeV beam: $-3.5 < y_{\text{CM}} < 0.5$
  - With 2.76 TeV beam: $-3 < y_{\text{CM}} < 1$
  - $\theta_{\text{min}} = 10$ mrad

- **Multi-purpose detector**
  - Vertex
  - Tracking (+ dipole magnet)
  - RICH
  - Calorimetry
  - Muons

- **High boost** → forward and as compact as possible detector
Detector dimension

\[
1.3 < y_{lab} < 5.3 \\
\theta_{min} = 10 \text{ mrad}
\]

<table>
<thead>
<tr>
<th>Detector</th>
<th>(Z_{min}/Z_{max})</th>
<th>(R_{min}/R_{max})</th>
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<tbody>
<tr>
<td>Vertex</td>
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<tr>
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<td>0.8/170 cm</td>
</tr>
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- **Technology**
  - Vertex, tracker: pixel detectors
  - Ultra-granular EMCal: Tungsten/Si (Calice - ILC)
  - Muons: Magnetize Fe (Minos)
  - ...
Detector dimension

1.3 < y_{lab} < 5.3
\theta_{\text{min}} = 10 \text{ mrad}

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• Technology
  - Vertex, tracker: pixel detectors
  - Ultra-granular EMCal: Tungsten/Si (Calice - ILC)
  - Muons: Magnetize Fe (Minos)
  - ...
Longitudinal polarized target: helicity distr.

Parton helicity distribution in a **longitudinally polarized nucleon**:
Longitudinal polarized target: helicity distr.

parton helicity distribution in a **longitudinally polarized nucleon**:

- Experimental probes @ AFTER
  - $W^+/- \rightarrow$ individual helicity distribution of quark and anti-quark