QUESTIONS ON THE BETA-BEAM FACILITY

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• Production: which is the maximum number of He/Ne ions that can be produced? and of Li/B?

• Acceleration: which is the maximum $\gamma$ achievable at CERN within the LHC upgrade programme?

• Are there activation problems at the RCS, PS, SPS? What about PS2 and SPS+?

• Storage ring: which is the maximum number of ions that can be stacked, relaxing the duty cycle? which geometry: two baselines are possible? Triangle vs two racetracks? livestimes....
Physics-reach scaling

Same flux shape
\[
\frac{\gamma_{\text{He/Ne}}}{\gamma_{\text{Li/B}}} = \left( \frac{E_{0}^{\text{Li/B}}}{E_{0}^{\text{He/Ne}}} \right)
\]

Same statistics
\[
\frac{N_{\beta}^{\text{He/Ne}}}{N_{\beta}^{\text{Li/B}}} = \left( \frac{E_{0}^{\text{He/Ne}}}{E_{0}^{\text{Li/B}}} \right)^2
\]

Is it easier to increase \( \gamma \) or the number of ions in the storage ring?
At fixed $\gamma$...
The CERN-Memphys project

Detector options

UNO

0.65 Mton total mass

100 kton liquid Argon TPC detector

Experiments for CP violation: a giant liquid Argon scintillation, Cerenkov and charge imaging experiment.
He/Ne with 1Mton WC: systematics dominated!
He/Ne with 1 Mton WC: systematics dominated!
He/Ne with 1Mton WC: systematics dominated!
TASD

An extrapolation of Minerva

Suited for low energy muons

22.5 Kton Mass
TASD

An extrapolation of Minerva

Suited for low energy muons

22.5 Kton Mass

Muon identification efficiency for Magnetized TASD
He/Ne with TASD: background dominated!

He/Ne with TASD: background dominated!

He/Ne with TASD: background dominated!

Magnetized Iron Detector

40-50 Kton Mass

Good Muon Charge Identification
Magnetized Iron Detector

40-50 Kton Mass

Good Muon Charge Identification
Magnetized Iron Detector

Good Muon Charge Identification

40-50 Kton Mass

Eff

0.5
0.4
0.3
0.2
0.1
0.1
0

Muon identification efficiency

$E_{\nu}$
Li/B with MIND: statistics dominated!
Li/B with MIND: statistics dominated!

\[ 2 \times 10^{18} \]
Li/B with MIND: statistics dominated!

P. Coloma et al. arXiv:0712.0796
Li/B with MIND: statistics dominated!

P. Coloma et al. arXiv:0712.0796
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1. with $^6$He/$^{18}$Ne

$<E_\nu> = 300$ MeV  \hspace{1cm} \gamma \sim 100  \hspace{1cm} \text{P. Zucchelli hep-ph/0107006}$

$L = 130$ Km
2. with $^{6}\text{He}/^{18}\text{Ne}$

$\langle E_\nu \rangle = 1.2 \text{ GeV}$  
$L = 650 \text{ Km}$  
$\gamma \sim 350$

J. Burguet-Castell et al. hep-ph/0312068
J. Burguet-Castell et al. hep-ph/0503021
2. with $^6\text{He}/^{18}\text{Ne}$

$<E_\nu> = 1.2$ GeV  \quad \gamma \sim 350$

L = 650 Km

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J. Burguet-Castell et al. hep-ph/0503021
Significant gain for changing $\gamma$ at fixed ions!

99% CL sensitivity to CP violation, for 4.4 Mton y

- $\gamma = 60,100$ and $L = 130$ km
- $\gamma = 120,120$ and $L = 130$ km
- $\gamma = 150,150$ and $L = 300$ km
- $\gamma = 350,350$ and $L = 730$ km

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J. Burguet-Castell et al. hep-ph/0503021
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<table>
<thead>
<tr>
<th></th>
<th>$^6\text{He}$</th>
<th>$^{18}\text{Ne}$</th>
<th>$^8\text{Li}$</th>
<th>$^8\text{B}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LINAC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Injected ions/s)/$10^{12}$</td>
<td>17.1 [82]</td>
<td>5.25 [82]</td>
<td>17.1</td>
<td>17.1</td>
</tr>
<tr>
<td>$\gamma_{\text{final}}$</td>
<td>1.11 [82]</td>
<td>1.11 [82]</td>
<td>1.10</td>
<td>1.10</td>
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<tr>
<td><strong>RCS ($L = 251$ m)</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(Injected ions/s)/$10^{12}$</td>
<td>8.53 [82]</td>
<td>2.62 [82]</td>
<td>8.53</td>
<td>8.53</td>
</tr>
<tr>
<td>$\gamma_{\text{final}}$</td>
<td>1.84 [82]</td>
<td>2.77 [82]</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>$P$ (KW)</td>
<td>$\lesssim 0.1$</td>
<td>$\lesssim 0.1$</td>
<td>$\lesssim 0.1$</td>
<td>$\lesssim 0.1$</td>
</tr>
<tr>
<td>$t_{\text{acc}}$ (s)</td>
<td>0.0475 [82]</td>
<td>0.0475 [82]</td>
<td>0.0475</td>
<td>0.0475</td>
</tr>
<tr>
<td><strong>PS ($L = 628$ m)</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(Injected ions/s)/$10^{12}$</td>
<td>1.84 [82]</td>
<td>1.25 [82]</td>
<td>1.84</td>
<td>1.84</td>
</tr>
<tr>
<td>$\gamma_{\text{final}}$</td>
<td>9.33 [82]</td>
<td>15.53 [82]</td>
<td>10.3</td>
<td>17.4</td>
</tr>
<tr>
<td>$P$ (KW)</td>
<td>0.8</td>
<td>1.0</td>
<td>1.1</td>
<td>1.3</td>
</tr>
<tr>
<td>$P/L$ (W/m)</td>
<td>1.3</td>
<td>1.6</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>$t_{\text{acc}}$ (s)</td>
<td>0.8 [82]</td>
<td>0.8 [82]</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>SPS ($L = 6912$ m)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Injected ions/s)/$10^{12}$</td>
<td>1.59 [82]</td>
<td>1.20 [82]</td>
<td>1.61</td>
<td>1.68</td>
</tr>
<tr>
<td>$\gamma_{\text{final}}$</td>
<td>100</td>
<td>100</td>
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<tr>
<td>$P$ (KW)</td>
<td>3.0</td>
<td>1.8</td>
<td>3.4</td>
<td>2.2</td>
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<tr>
<td>$P/L$ (W/m)</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>0.3</td>
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<tr>
<td>$t_{\text{acc}}$ (s)</td>
<td>2.54 [82]</td>
<td>1.42 [82]</td>
<td>2.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Numbers taken from
P. Coloma et al. arXiv:0712.0796,
in good agreement with
http://beta-beam-parameters.web.cern.ch

Big problem at the PS!

No problem.
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Atmospheric neutrino background

Duty factor = \( \frac{\nu \Delta t_{\text{bunch}} N_{\text{bunch}}}{L_{\text{ring}}} \) < \( 10^{-n} \)
Atmospheric neutrino background

\[ \Phi \propto E^2 \]

He/Ne at \( \gamma = 100 \quad B = 10^3 \)

Duty factor = \( (\nu \Delta t_{\text{bunch}} N_{\text{bunch}}) / L_{\text{ring}} < 10^{-n} \)
Atmospheric neutrino background

\[ \Phi \propto E^2 \]

He/Ne at \( \gamma = 100 \quad B = 10^3 \)

He/Ne at \( \gamma = 350 \quad B = 10^2 \)

Duty factor = \( (\nu \Delta t_{\text{bunch}} N_{\text{bunch}}) / L_{\text{ring}} < 10^{-n} \)
Atmospheric neutrino background

Duty factor = \( \frac{\nu \Delta t_{\text{bunch}} N_{\text{bunch}}}{L_{\text{ring}}} \) < 10\(^{-n}\)

\[
\Phi \propto E^2
\]

He/Ne at \( \gamma = 100 \) \( B = 10^3 \)

He/Ne at \( \gamma = 350 \) \( B = 10^2 \)

Li/B at \( \gamma = 350 \) \( B = 10^1 \)
4. with $^8\text{Li}/^8\text{B}$

Two baselines

$\langle E_\nu \rangle = 4.5 \ \text{GeV}$
$L \sim 1500 \ \text{Km}$
$L = 7000 \ \text{Km}$

S. K. Agarwalla et al. hep-ph/0610333
S. K. Agarwalla et al. hep-ph/0611233
P. Coloma et al. arXiv:0712.0796
Is there a bottleneck?
Where?

a. In the production?
b. In the acceleration (losses, space charge)?
c. Stacking? duty factor is a problem?