ν–Factory Front End Phase Rotation Simulations

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Related by Richard Fernow
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Outline

• Neutrino Factory Front End Optimization
  • Improve neutrino factory scenario
  • For International Scoping study

• “High-frequency” Buncher and $\phi-\delta E$ Rotation
  • Study 2A scenario, Obtains $\sim 0.2 \mu/p$
  • Gas filled cavities
    - Higher gradients? In magnetic fields?
    - Cooling in buncher and rotator/shorter cheaper?
      System
Neutrino Factory – Study 2A

- Proton driver
  - Produces proton bunches
  - 8 GeV $10^{15}$ p/s
- Target and drift
  - $\pi \rightarrow \mu$ (> 0.2 $\mu$/p)
- Buncher, bunch rotation, cool
- Accelerate $\mu$ to 20 GeV
  - Linac, RLA and FFAGs
- Store at 20 GeV (0.4ms)
  - $\mu \rightarrow e + \nu_\mu + \nu_e^*$
- Long baseline $\nu$ Detector
  - $>$10$^{20}$ $\nu$/year
Study2AP June 2004 scenario

- **Target** – Hg–jet within 20T solenoid
- **Drift** – 110.7m – within 1.75T solenoid
- **Bunch** – 51m
  - $V\delta(1/\beta) = 0.0079$
  - 12 rf freq., 110MV
  - 330 MHz → 230MHz
- **$\phi$–E Rotate** – 54m – (416MV total)
  - 15 rf freq. 230 → 202 MHz
  - $P_1 = 280, P_2 = 154$ $\delta N_V = 18.032$
- **Match and cool** (80m)
  - 0.75 m cells, 0.02m LiH
- “Realistic” fields, components
Simplest Modification from Study 2A

- **Add gas** + higher gradient to obtain **cooling within rotator**
- ~300MeV energy loss in cooling region
- Rotator is 54m;
  - Need ~4.5MeV/m H₂ Energy
  - 133atm, 295°C K gas
  - ~250 MeV energy loss
- Alternating Solenoid lattice in rotator
- 20MV/m rf
- Lattice changes
“Final” configuration

- Drift, buncher as before:
  - 300 → 230MHz rf
  - 51m, $V = 3 \frac{z}{z_0} + 9\left(\frac{z}{z_0}\right)^2$
- “match” from 2 T to 2.75T alternating solenoid at end of buncher
- Rotator lattice
  - 0.75m cells, 0.5m rf/cell
  - 133A H₂, 3.4 MeV/cell
  - $V = 20\text{MV/m}$, $\phi = 20^\circ$
  - 54m
- Post Rotator Cooling lattice
  - $V = 16\text{MV/m}$
  - 133A H₂
ICOOI results—gas cavities

- ~0.20 μ/p within reference acceptance at end of φ–E Rotator
- ~0.10 μ/p within restricted acceptance (ε⊥<0.015m)
- Rms emittance cooled from ε⊥ = 0.019 to ε⊥ = ~0.009
- Longitudinal rms emittance ≈0.075

- Continuing Study 2A cooling does not greatly improve acceptance
Cooling simulation results
Modify initial solution

- Change pressure to 150Atm
- Rf voltage to 24 MV/m
- Transverse rms emittance cools 0.019 to ~0.008m
- Acceptance ~0.22μ/p at ε_T < 0.03m
- ~0.12μ/p at ε_T < 0.015m
Same geometry – Be Windows

- Replace 150 A gas with 0.65cm thick Be windows on cavities
- Similar dynamics as H₂ but
- **Much worse** Study 2A performance (?)
- Transverse emittance cooling: 0.019 → 0.0115
- Muons within Study 2A acceptance:
  - 0.134 μ/p (εt < 0.03)
  - 0.056 μ/p (εt < 0.015)
  - Needs reoptimization?
Try LiH Windows

- Replace 150 A gas with 1.2cm thick LiH windows on cavities
- Similar dynamics as Be but
- **Slightly better** than Be performance (?
- Transverse emittance cooling : 0.019 → 0.0102
- Muons within Study 2A acceptance:
  - **0.160 μ/p** (ε_t < 0.03)
  - **0.075 μ/p** (ε_t < 0.015)

Needs reoptimization?
Cost estimates:

- Costs of a neutrino factory (MuCOOL-322, Palmer and Zisman):

  Combining cooling and phase rotation may reduce cost by ~ 100M$
## Component cost basis

### Table 5: Study Ib Buncher and Phase Rotation Costs

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<tr>
<th></th>
<th>M$</th>
<th>Length</th>
<th>k$/m</th>
<th>GeV</th>
<th>k$/GeV</th>
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**Scaling**
- length
- length x $(BR^2)^{0.577}$
- length $V/\mathcal{E}$
- length x $(BR^2)^{0.577}$
- length $V/\mathcal{E}$
- length $V/\mathcal{E}$
- length $V/\mathcal{E}$
**Cost impact of Gas cavities**

- Removes 80m cooling section (-185 M$)

- Increase $V_{rf}'$ from 12.5 to 20 or 24 MV/m
  - Power supply cost $\propto V'^2$ (?)
  - 44 M$ \rightarrow 107$M$ or 155$M$

- Magnets: 2T $\rightarrow$ 2.5T Alternating Solenoids
  - 23 M$ \rightarrow 26.2$ M$

- Costs due to vacuum $\rightarrow$ gas-filled cavities (?)

- Total change:
  - Cost decreases by 110 M$ to 62 M$ (?)
Summary

• High-frequency Buncher and $\phi-\delta E$ Rotator (v-Factory)
  • Variations (Poklonskiy may help),
  • Shorter systems ??
  • Other frequencies ?

• Gas-filled rf cavities
  • Higher gradient??
  • Optimize $V'$
  • Cool in buncher rotator

To do:
• Optimizations, Best Scenario, cost/performance ...
Motivation ...

Um... why are you here?

Originally I was seduced by the smell of your freshly brewed coffee and tempting pastries.

But now I'm all about cross-charging my time to your project.

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