Front End – present status

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March 31, 2015
Outline

- **Front End for Muon Collider/ Neutrino Factory**
  - Baseline for MAP
    - 8 GeV proton beam on Hg target
  - 325 MHz
    - With Chicane/Absorber

- **Current status**
  - New targetry
    - 6.75 GeV on C target
  - New Mars generated beams
    - Mars output much different from previous version
  - Buncher-Rotator with H₂ gas
    - rematches OK except for loss at beginning of buncher
    - can cool and rotate simultaneously
325 MHz System “Collider”

- **Drift**
  - 20 T → 2 T

- **Buncher**
  - $P_o = 250$ MeV/c
  - $P_N = 154$ MeV/c; $N = 10$
  - $V_{rf} : 0 \rightarrow 15$ MV/m
    - (2/3 occupied)
  - $f_{RF} : 490 \rightarrow 365$ MHz

- **Rotator**
  - $V_{rf} : 20$ MV/m
    - (2/3 occupied)
  - $f_{RF} : 364 \rightarrow 326$ MHz
  - $N = 12.045$
  - $P_o, P_N \rightarrow 245$ MeV/c

- **Cooler**
  - 245 MeV/c
  - 325 MHz
  - 25 MV/m
  - 2 1.5 cm LiH absorbers /0.75m
Simulation Results

- Simulation obtains
  - ~0.125 μ/p within acceptances
  - with ~60 m Cooler
  - 325 MHz - less power
  - shorter than baseline NF

- But
  - uses higher gradient
  - higher frequency rf → smaller cavities
  - shorter than baseline NF
  - more bunches in bunch train
New Proton Driver parameters

- **6.75 GeV p, C target**
  - 20 → 2 T short taper
    - ~ 5 m (previously 15)
  - X. Ding produced particles at z = 2 m using Mars
  - short initial beam

- **Redo ICOOL data sets to match initial beam**
  - ref particles redefined
    - in for003.dat
    - and for001.dat
Following Scott’s review of front end

- Use his initial distributions (obtained by X. Ding)
  - 8 GeV protons on Hg target
    - + and minus
  - 6.75 GeV protons on C target
  - Start beam from z = 10 m
    - must retranslate into ICOOL reference particles
  - Early losses on apertures have already occurred
    - 23 cm apertures
ICOOL translation tips

- start at “z = 10 m”
  - (particle time zero is at -1 m)
- reference particles
  - 250 MeV/c ; 154 MeV/c μ⁺
    - 165.75 MeV ; 81.1 MeV μ⁺
  - time set by 1m as 6.75 GeV proton + 10 m as μ⁺
  - reference particles set in for003.dat, not for001.dat

In ICOOL for001.dat

REFP
2 0 0 3
REF2
2 0 0
First simulation results

Simulation results

- Hg target 8 GeV - end of cooling
  - $\sim 0.0756 \mu^+ / p$; $\sim 0.0880 \mu^- / p$;

- C target 6.75 GeV p
  - $\sim 0.0613 \mu^+ / p$; $\sim 0.0481 \mu^- / p$;
    - $0.0726 \mu^+ / p$; $\sim 0.0570 \mu^- / p$ when multiplied by $8/6.75$

- Previous front ends had $\sim 0.1$ to $\sim 0.125 \mu / p$
Progression of beam through system

- $z = 11 \text{ m}$
- $z = 104 \text{ m}$
- $z = 135 \text{ m}$
Simulations capture typically somewhat less than before

- Big difference in MARS production model
  - Mars Inclusive $\rightarrow$ LAQGSM=1
- Drop in production for $\sim 8$ GeV
  - Are previous MARS simulations that showed an advantage in production for $\sim 8$ GeV still true?

- IQGSM=0: exclusive CEM (cascade exciton model?) for $E < 3$ GeV, MARS inclusive for $E > 5$ GeV, LAQGSM for some special cases. Old MARS default.
- IQGSM=1: CEM for $E < 0.3$ GeV, LAQGSM for $0.5$ GeV < $E$ < $8$ GeV, MARS inclusive for $E > 10$ GeV. New MARS default.
Add gas-filled rf in buncher/rotator

- **34 - 100 atm equivalent**
  - 1.14 MeV/m
    - 34 atm
  - 3.45 MeV/m
    - 100 atm

- for 34 atm
  - add ~2 MV/m to rf

- **First tries with ICOOL**
  - GH in buncher 1 atm
    - no change in capture
  - Change to 34 atm by
    - DENS GH 34.0
  - Runs OK but
    - reduces capture by 20%
    - mostly from low-E muons
      - shorter bunch train

![Graph](image-url)
Updated gas-filled front end

- added gas in rotator
  - 34 atm
  - $dE/dx$

- Increased rf a bit
  - Buncher $15z \rightarrow 2 + 20(z/24) \text{ MV/m}$
  - Rotator $20 \rightarrow 25$
    - ref particles decelerate to 230 Mev/c
  - Cooler $25 \rightarrow 28 \text{ MV/m}$

- Results are not so bad
  - 8 GeV Hg $^+ \rightarrow 0.0718 \mu/p$
  - 8 GeV Hg $^- \rightarrow 0.0773 \mu/p$
  - 6.75 GeV C $^+ \rightarrow 0.0539 \mu^+/p$
  - 6.75 GeV C $^- \rightarrow 0.0430 \mu^-/p$
  - ~10% worse than baseline

- Tweak of reference particle to fit ICOOL features
  - ref particle acceleration fitted to
  - use phase model 4
    - tracks reference particles energy loss in drft/absorber but not in rf
    - fixed energy gain/loss in rf
FrontEnd variations

- Reduce buncher gas to 17 atm
  - ~ 10% better
  - back to ~ baseline
  - ~0.062 $\mu^+ / p$

- change decelerating rotator back to constant energy rotator
  - $C \rightarrow \sim 0.063 \mu^+ / p$
  - about the same
  - no real advantage/disadvantage in deceleration

- Note initial beam is “cooled”, but only in one dimension
  - $B = 2 \, T$ - no field flip
  - Angular momentum increases

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Effect of new initial distributions

- Redo with old initial beams
  - 2010 Hg 8 GeV p
    - $0.114 \mu^+/p$
  - 2014 Hg 8 GeV p
    - $0.112 \mu^+/p$
  - Compare with current BEAM
    - Hg 8 GeV p
    - $0.072 \mu^+/p$

- Major difference is newer MARS model
34 --- 34 atm

600 MeV/c

0.058 $\mu^+$/p

z = 72

z = 108

20m 40m

17 --- 34 atm

0.065 $\mu^+$/p

z = 150

z = 108

20m 40m

-20m 40m
Beam difference notes

- Most of loss in intrinsic performance is from gas in buncher
  - Beam enters completely unbunched
  - Initial rf is weak; and slowly increases

- After some initial loss, SIMILAR TO GAS-FREE BASELINE
Increase rotator to 100 atm

- Buncher at 17 atm
  - LESS INITIAL LOSS
- With V = 20/25/28
  - ~0.059 µ/p (C 6.75)
  - ~10% less than 17/34
- Increase Rotator gradient to 28 MV/m
  - to compensate energy loss
- Fairly good performance
  - ~0.063 µ/p (C 6.75)

- More cooling in Rotator
  - 1-D cooling (2T solenoid)
  - one mode highly damped
- Significant initiation of cooling
  - (integrating rotator/cooler)
  - shortens following cooler

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Tried higher

- 100 atm → 150 atm

- Preliminary results
  - seems a bit worse than 100 atm

- Not much more cooling
  - limited by 1-D cooling in fixed field ??
Future projects

➢ Go to longer system
  ▪ B/R/C → 24 m / 30 m / 50 m
  ▪ D → 17 / 100 atm ??

➢ try alternating solenoid in rotator ?
Next steps

CONFERENCE CALL

WALLY, CAN YOU TAKE THE LEAD ON THAT?

THIS IS TED. I JUST JOINED THE CALL. I'LL TAKE CARE OF THAT FOR WALLY.

THANKS, TED.

I'M CRUSHING IT TODAY.