MARS Target Yield Studies

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Introduction

• Using MARS (v15.07) and Study-II geometry to find pion & muon yields

• 10 GeV proton beam hitting cylindrical tungsten rod in 20 T field region
  – Rod lengths: 15, 20, 25 and 30 cm
  – Rod radii: 0.75, 1.00, 1.50 cm; beam radius = rod radius
  – Rod tilt: 0, 20, 50, 100, 150, 200, 250, 300 mr; beam tilt = rod tilt

• Counting number of \(\pi\) and \(\mu\) (per proton) along different \(z\) planes within target aperture \((z \leq 6 \text{ m})\) directly from MARS output

• Using ICOOL (v3.05) to get \(\mu\) acceptance for \(6 \leq z \leq 300 \text{ m}\) cooling channel
  – plots with “final” in the title are results showing the accepted \(\mu\) yield at the end of the cooling channel. Using input files from Study-II website.

• Generating 100k events for each scenario. CPU time \(\sim 12-15\) hours per MARS + ICOOL job.
Charge averaged $\pi, \mu$ yield per proton at $z = 6$ m for $r_{\text{beam}} = 0.75$ cm.
Final $\mu$ acceptance per proton at end of cooling channel for $r_{\text{beam}} = 0.75 \text{ cm}$. 

![Graph showing the final yield per proton as a function of $\theta_{\text{rod}}$ (in mr) for different lengths of the cooling channel. The graph includes lines for L15cm in green, L20cm in red, L25cm in blue, and L30cm in black. The y-axis represents the final yield per proton in percentage, and the x-axis represents $\theta_{\text{rod}}$ (in mr) ranging from 0 to 300.]}
Charge averaged $\pi, \mu$ yield per proton at $z = 6$ m for $r_{\text{beam}} = 1$ cm.
Final $\mu$ acceptance per proton at end of cooling channel for $r_{\text{beam}} = 1\,\text{cm}$.
Charge averaged $\pi, \mu$ yield per proton at $z = 6$ m for $r_{\text{beam}} = 1.5$ cm.
Final $\mu$ acceptance per proton at end of cooling channel for $r_{\text{beam}} = 1.5$ cm.
• The following pages show 2D plots of the $\pi$, $\mu$ yields as a function of rod tilt and rod length for various rod radii.

• $z = 6 \text{ m}$ plots are the charge averaged $\pi, \mu$ yields per proton from MARS output

• Final $\mu$ plots are the $\mu$ yields per proton within the acceptance at the end of the cooling channel from ICOOL simulations.

• Yield is represented by a colour density (scale on the right hand side).

• Black box highlights the maximum yield over all angles and rod lengths for the given rod/beam radius. Numbered boxes represent the maximum yield for the given tilt-length pair.
$z=6\text{m} \mu,\pi$ yield ($y$) per proton for $r_{rod} = r_{beam} = 0.75\text{cm}$

![Graph showing the yield ($y$) per proton for different values of $r_{rod}$ and $L_{rod}$ with values such as 26.45%, 28.04%, 28.69%, and 28.77% indicated at specific points.]
Final $\mu$ yield ($Y$) per proton for $r_{rod} = r_{beam} = 0.75\text{cm}$

$Y$ (%)

$L_{rod}$ (cm)

$\theta_{rod}$ (mrad)

7.28 %

7.78 %

7.92 %

7.72 %
$z=6m \mu, \pi$ yield ($y$) per proton for $r_{rod} = r_{beam} = 1cm$
Final $\mu$ yield ($Y$) per proton for $r_{rod} = r_{beam} = 1\text{cm}$
$z=6m \mu, \pi$ yield ($y$) per proton for $r_{rod} = r_{beam} = 1.5\text{cm}$

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Final $\mu$ yield ($Y$) per proton for $r_{rod} = r_{beam} = 1.5$ cm

$Y$ (%) vs $L_{rod}$ (cm) and $\theta_{rod}$ (mrad)

- $5.90\%$ at $L_{rod} = 15$ cm and $\theta_{rod} = 0$
- $5.76\%$ at $L_{rod} = 15$ cm and $\theta_{rod} = 50$
- $5.71\%$ at $L_{rod} = 25$ cm and $\theta_{rod} = 200$
- $5.42\%$ at $L_{rod} = 30$ cm and $\theta_{rod} = 200$

• The following plots show some more detailed MARS and ICOOL output
  
  – Top left: charge averaged $\pi$, $\mu$ yield per proton for $z \leq 6$ m from MARS for the single inclined rod in the target region

  – Top right: $\mu$ acceptance along $z$ from ICOOL simulation

  – Bottom left: Transverse emittance of the $\mu$ particles from ICOOL

  – Bottom right: Longitudinal emittance of the $\mu$ particles from ICOOL

• Each separate page shows the plots for all rod tilt angles for a given rod radius and rod length.
\[ r_{\text{rod}} = 0.75\text{cm}, \quad L_{\text{rod}} = 30\text{cm} \]
$r_{rod} = 0.75\text{cm}, L_{rod} = 25\text{cm}$
$r_{rod} = 0.75\text{cm}, L_{rod} = 20\text{cm}$
$r_{rod} = 0.75\text{cm}, L_{rod} = 15\text{cm}$
$r_{rod} = 1\text{cm}, L_{rod} = 30\text{cm}$
\( r_{\text{rod}} = 1 \text{cm}, L_{\text{rod}} = 25 \text{cm} \)

### Graphs

- **Top Left:**
  - \( \pi_{\mu} \text{ yield per proton} \)
  - \( z \text{ (m)} \)
  - Lines for different \( r \) values:
    - 0mr
    - 20mr
    - 50mr
    - 100mr
    - 150mr
    - 200mr
    - 250mr
    - 300mr

- **Top Right:**
  - \( \text{accepted } \pi_{\mu} \text{ yield per proton} \)
  - \( z \text{ (m)} \)
  - Lines for different \( L \) values:
    - 0
    - 20
    - 40
    - 60
    - 80
    - 100
    - 120
    - 140
    - 160
    - 180
    - 200
    - 220

- **Bottom Left:**
  - \( \xi_{\text{L}} \text{ (mm mrad)} \)
  - \( z \text{ (m)} \)
  - Lines for different \( \xi_{\text{L}} \) values:
    - 0
    - 20
    - 40
    - 60
    - 80
    - 100
    - 120
    - 140
    - 160
    - 180
    - 200
    - 220

- **Bottom Right:**
  - \( \xi_{\text{v}} \text{ (mm)} \)
  - \( z \text{ (m)} \)
  - Lines for different \( \xi_{\text{v}} \) values:
    - 0
    - 20
    - 40
    - 60
    - 80
    - 100
    - 120
    - 140
    - 160
    - 180
    - 200
    - 220
\( r_{\text{rod}} = 1\text{cm}, L_{\text{rod}} = 20\text{cm} \)
$r_{\text{rod}} = 1\text{cm}, L_{\text{rod}} = 15\text{cm}$

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$r_{\text{rod}} = 1.5\text{cm}, L_{\text{rod}} = 30\text{cm}$
\( r_{\text{rod}} = 1.5\text{cm}, L_{\text{rod}} = 25\text{cm} \)
$r_{\text{rod}} = 1.5\text{cm}, \ L_{\text{rod}} = 20\text{cm}$
$r_{\text{rod}} = 1.5\text{ cm}, L_{\text{rod}} = 15\text{ cm}$

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