NuFact target shape

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Reminder: Optimisation of the tungsten target shape*

**Idea**

10 GeV protons parabolic beam

8 segments (inner and outer cylinder; 4 divisions along the length)

each segment -> 2 possible density values (50(10)% and 100% of tungsten density)

number of different configurations = $2^8 = 256$

It means 256 MARS simulations (100,000 incoming protons per job)

Let MARS decide what is the optimal configuration of the target (on the basis of the pions yield)

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*http://hepunix.rl.ac.uk/uknf/wp3/shocksims/mars_dyna/Tungsten/Target_Shape.ppt
Reminder: Optimisation of the tungsten target shape*

Results

If beam radius = target radius  The best option is to have full 100% density target

If beam diameter is smaller than target diameter  (here 2x smaller)...

...the optimal target shape looks like this**:

This is the result if we count all pions (no magnetic field)

What is the result for the target in a Neutrino Factory?

*http://hepunx.rl.ac.uk/uknf/wp3/shocksims/mars_dyna/Tungsten/Target_Shape.ppt
**Using a better (finer) segmentation we would obviously have some kind of paraboloid shape
20 T magnetic field

Cuts on pions $p_T$ and $p_L$

Pions counted a few meters down within estimated aperture

Beam is parabolic (as in previous analysis)

$2^8$ different configurations (as in previous analysis) $\rightarrow$ calculations take much more time now

Target length is constant $= 20$ cm (as in previous analysis)

In fact, we have 2 'different' studies here:

*Optimisation of the target density - 100% and 50% density combinations*

*Optimisation of the target shape - 100% and 10(1)% density combinations*
Optimisation of the NF tungsten target shape
Beam radius 0.5 cm; target radius = 1 cm

Results: pions yield shown as well as a few characteristic target configurations (best and worst ones included)

Best configuration:
- target radius -> beam radius
  (“we don’t need additional material”)

That’s the difference when comparing with the ‘general’ case!
Optimisation of the NF tungsten target density

Beam radius = target radius = 0.5 cm

Results: pions yield shown as well as a few characteristic target configurations (best and worst ones included)

So, the best possible case is when target radius = beam radius; next plots show the effect of reduced density

Best / “100%” = 1.04

“100%” / “50%” = 1.18

Colour code:
- 100% density
- 50% density
Optimisation of the NF tungsten target density

Beam radius = target radius = 1 cm

Results: pions yield shown as well as a few characteristic target configurations (best and worst ones included)

Best / “100%” = 1.07

“100%” / “50%” = 1.10

Colour code:
- 100% density
- 50% density
Optimisation of the NF tungsten target density

Beam radius = target radius = 1.5 cm

Results: pions yield shown as well as a few characteristic target configurations (best and worst ones included)

Best / “100%” = 1.10

“100%” / “50%” = 1.02
A few words about results (part I)

• In general case*, if beam radius is smaller than target radius the optimal target shape is:

• For particular conditions at Neutrino Factory it is much better when the beam radius is equal to the target radius

• In general case*, if beam radius = target radius then the best option is to have full 100% density target

• For particular conditions at Neutrino Factory we have different situation: some configurations with reduced density have higher yields (this effect increases with increasing beam(target) radius)

• Ratio of yields for 100% and 50% density target is practically equal to 1 for 1.5 cm beam(target) radius (this ratio increases with decreasing beam(target) radius)

• So, it seems that for particular conditions at Neutrino Factory we should have 'reduced' amount of material in front of the beam – this probably means different optimal shape of the target...

*http://hepunx.rl.ac.uk/uknf/wp3/shocksim/mars_dyn/Tungsten/Target_Shape.ppt
Optimisation of the NF tungsten target shape
Beam radius = target radius = 1 cm

Results: pions yield shown as well as a few characteristic target configurations (best and worst ones included)

Best / “100%” = 1.10
Optimisation of the NF tungsten target shape

Beam radius = target radius = 1.5 cm

Results: pions yield shown as well as a few characteristic target configurations (best and worst ones included)

Best / "100%" = 1.13
A few words about results (part II)

- In general case*, if beam radius = target radius then the best option is to have full 100% density target.

- For particular conditions at Neutrino Factory these shapes

  ![Target Shapes](http://hepunx.rl.ac.uk/uknf/wp3/shock sims/mars_dyna/Tungsten/Target_Shape.ppt)

  ‘produce’ 10 to 15% more pions than full cylinder.

*http://hepunx.rl.ac.uk/uknf/wp3/shock sims/mars_dyna/Tungsten/Target_Shape.ppt
Appendix: Configuration Number

Target has 8 segments (inner and outer cylinder; 4 divisions along the length). Segment numbers shown on the left.

'Density coefficient' of segment \( i \) is \( a_i \).
\( a_i = 1 \) for 100% density; \( a_i = 0 \) for low density (50% or 10%).
Each target configuration can be described by a set of density coefficients: \( a_1 a_2 a_3 a_4 a_5 a_6 a_7 a_8 \) (for example - 01110110).

If we define 'Binary weight' of segment \( i \) to be \( w_i \) (the values shown below)...

\[
\begin{align*}
w_1 &= 2^7 \\
w_2 &= 2^6 \\
w_3 &= 2^5 \\
w_4 &= 2^4 \\
w_5 &= 2^3 \\
w_6 &= 2^2 \\
w_7 &= 2^1 \\
w_8 &= 2^0
\end{align*}
\]

... then we can calculate the configuration number (x-axis on the previous slides):

\[
\text{Configuration Number} = \sum_{i=1}^{8} a_i w_i = a_1 2^7 + a_2 2^6 + a_3 2^5 + a_4 2^4 + a_5 2^3 + a_6 2^2 + a_7 2^1 + a_8 2^0 =
\]

\[
= a_1 \cdot 128 + a_2 \cdot 64 + a_3 \cdot 32 + a_4 \cdot 16 + a_5 \cdot 8 + a_6 \cdot 4 + a_7 \cdot 2 + a_8 \cdot 1
\]

For example, \( 01110110 = 0 \cdot 128 + 1 \cdot 64 + 1 \cdot 32 + 1 \cdot 16 + 0 \cdot 8 + 1 \cdot 4 + 1 \cdot 2 + 0 \cdot 1 = 118 \)
Update I

16 December 2008
When beam radius = 0.5 cm and target radius = 1 cm then the best scenario (see Slide 5) is to have 100% density core (0.5 cm radius) and less dense outer cylinder.

Optimal density of the outer cylinder? Around 10% of the tungsten density.
**Additional pion production by back-scattered hadrons**

beam radius = 0.5 cm

<table>
<thead>
<tr>
<th>Target shapes tested</th>
<th>Best configurations*</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Target shape 1" /></td>
<td><img src="image2" alt="Configuration 1" /></td>
</tr>
<tr>
<td><img src="image4" alt="Target shape 2" /></td>
<td><img src="image5" alt="Configuration 3" /></td>
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<td><img src="image6" alt="Target shape 3" /></td>
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<td><img src="image10" alt="Configuration 6" /></td>
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<tr>
<td><img src="image12" alt="Target shape 5" /></td>
<td><img src="image13" alt="Configuration 8" /></td>
</tr>
</tbody>
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*Colour code:*
- Black: 100% density
- Gray: 10% density

*Please note the configuration number. The corresponding pion yield is shown in the next slide.*
Additional pion production by back-scattered hadrons

When beam radius = 0.5 cm and target radius = 1 cm, the best scenario is to have 100% density core (0.5 cm radius) and less dense outer cylinder (see below). In this case we have 7% higher pion yield than for 0.5 cm target radius.

For some of the target shapes from previous slide, the pion yield increases for 12% comparing with 0.5 cm target radius case.