Horn studies for SPL-Superbeam

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OUTLINE

- Shape optimisation
  $\Rightarrow$ NuFact-horn
- Energy deposition
  $\Rightarrow$ MiniBoone-like horn, decay tunnel, beam dump

HORN – SHAPE OPTIMISATION

... various ideas

PROBLEM: A GOOD CRITERIA FOR OPTIMISATION

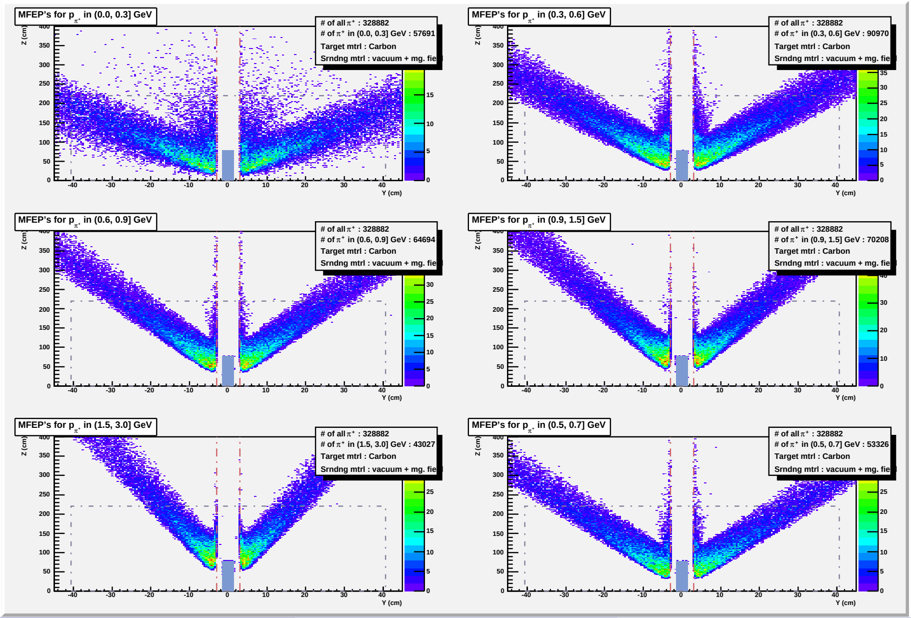
- sensitivity of physics parameters (θ_{13}, δ_{CP}), BUT requires full simulation and also details on detector
- optimise ν spectrum in solid angle corresponding to detector $\rightarrow$ still too time consuming, requires full simulation of target, horn, decay tunnel and beam dump
- optimise π spectrum afer exiting horn

... to be done

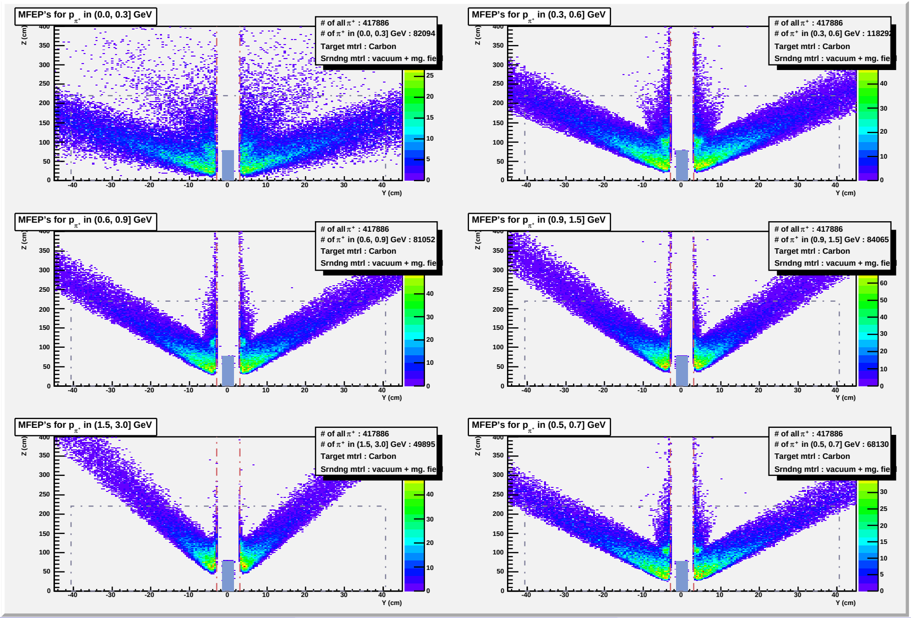
ANALYSIS OF "MAGNETIC FIELD EXIT POINTS" (=MFEP)

$\rightarrow$ shape should contain some conic form
looking at π tracks in magnetic field $\sim 1/r$ until they aligned with beam axis $\rightarrow$ that's where the inner conductor should be...

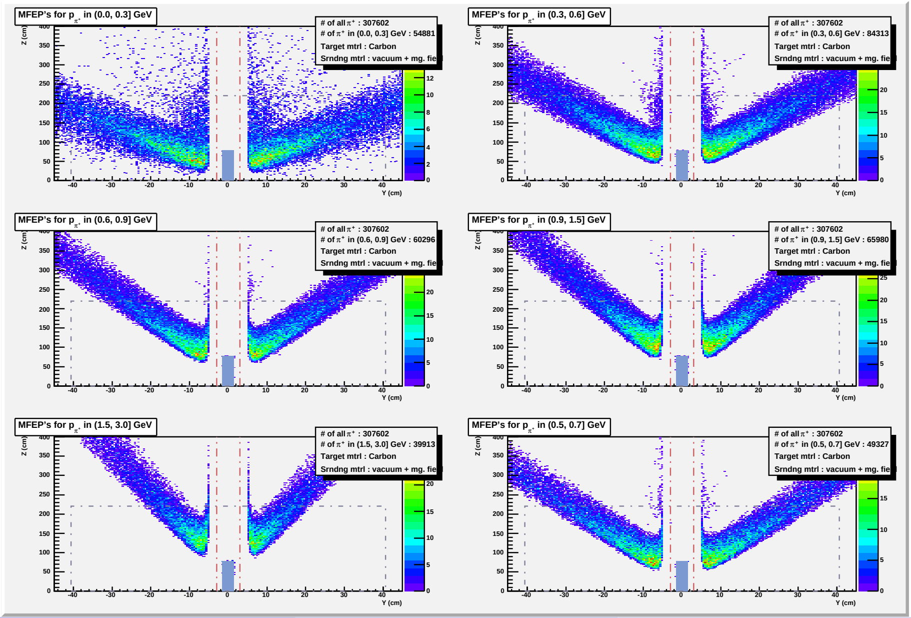
MFEP – inner $R = 3$ cm, $I = 300$ kA, $B_0 = 2$ Tesla



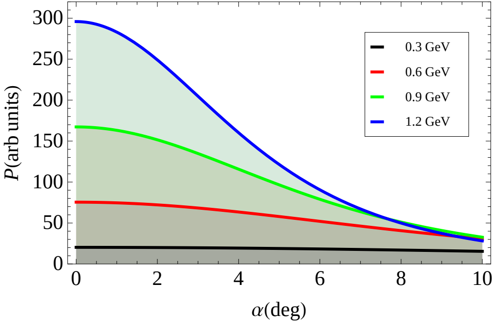
MFEP – INNER $R = 3$ CM, $I = 450$ KA, $B_0 = 3$ TESLA

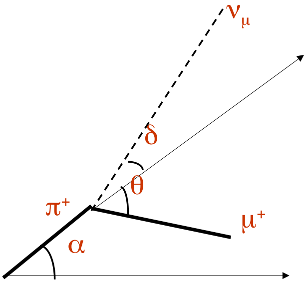


MFEP – INNER $R = 5$ CM, $I = 300$ KA, $B_0 = 1.2$ TESLA



HORN STUDIES – π DECAY KINEMATICS





Probability of ν_μ ending up in detector depends on

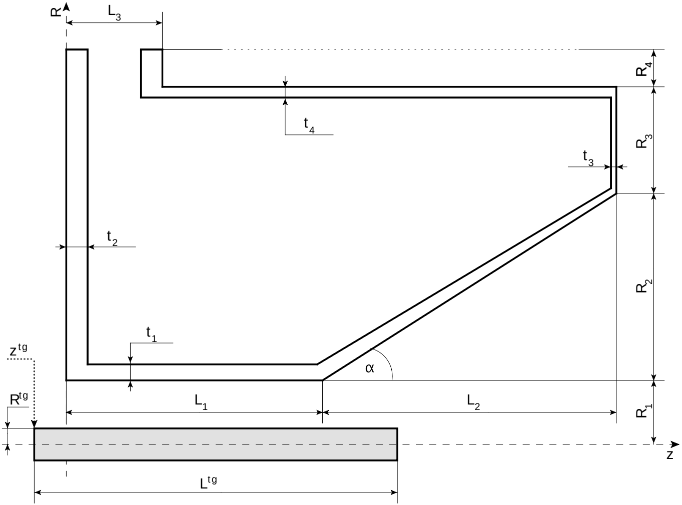
- π-momentum $\{0.3, 0.6, 0.9, 1.2\}$ GeV
- angle ($\delta = -\alpha$)

$\rightarrow$ more important to focus π's with large momentum

$$P(\alpha, L) = \frac{1}{4\pi}\frac{A}{L^2}\frac{1-\beta^2}{(1-\beta\cos\alpha)^2} \qquad \text{for} \qquad \text{dim(decay tunnel)} \ll L$$

REOPTIMISING NUFACT HORN (I)

- optimizing for longer Carbon target $L^{tg} = 78$ cm (previous Hg $L^{tg} = 30$ cm)
- removing reflector with current $I = 600$ kA introduced by Campagne/Cazes



keeping fixed:

$E^{kin} = 4.5$ GeV

$L^{tg} = 78$ cm
$R^{tg} = 1.5$ cm
$z^{tg} = 0$ cm

$L_3 = 3$ cm
$R_1 = 3.7$ cm
$R_4 = 4$ cm
$t_{1,2,3,4} = 3$ mm

$I = 300$ kA

varying: [cm]

$L_1 = \{20, 40, \ldots, 100\}$,
$L_2 = \{60, 80, \ldots, 140\}$,
$R_2 = \{11.6, 12.6, \ldots, 17.6\}$,
$R_3 = \{3, 4, 5, 6\}$

Campagne/Cazes:

$L_1 = 40$ cm,
$L_2 = 100$ cm,
$R_2 = 12.6$ cm,
$R_3 = 4$ cm

Reoptimising NuFact horn (II)

Scoring number of π's at $z = 3$ m through circular plane $R = 1$ m in π^+ focusing mode with selection of $(500 < p_\pi < 700)$ MeV

1) maximising the absolute number of π's

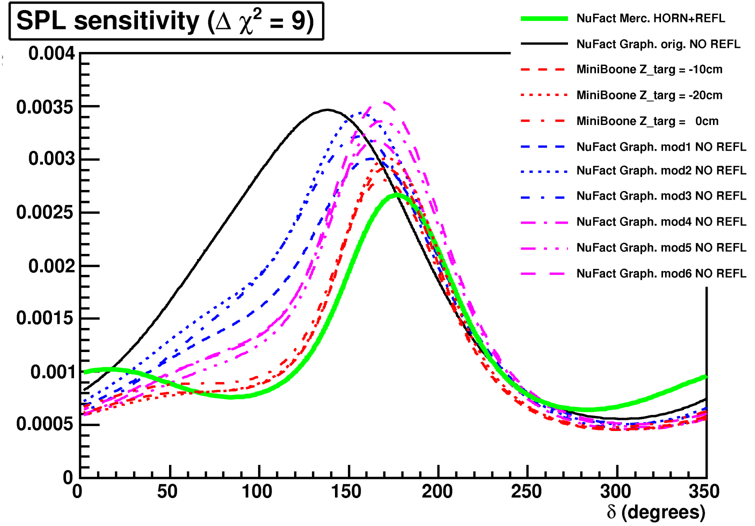
Ref.-Nr.	L_1 [cm]	L_2 [cm]	R_2 [cm]	R_3 [cm]	α [°]
mod1	60	120	17.6	6	8.3
mod2	60	140	17.6	6	7.2
mod3	60	120	17.6	5	8.3

2) maximising the ratio (number π^+)/(number π^-)

Ref.-Nr.	L_1 [cm]	L_2 [cm]	R_2 [cm]	R_3 [cm]	α [°]
mod4	80	100	17.6	6	10.0
mod5	100	60	14.6	5	13.7
mod6	100	80	16.6	6	11.7

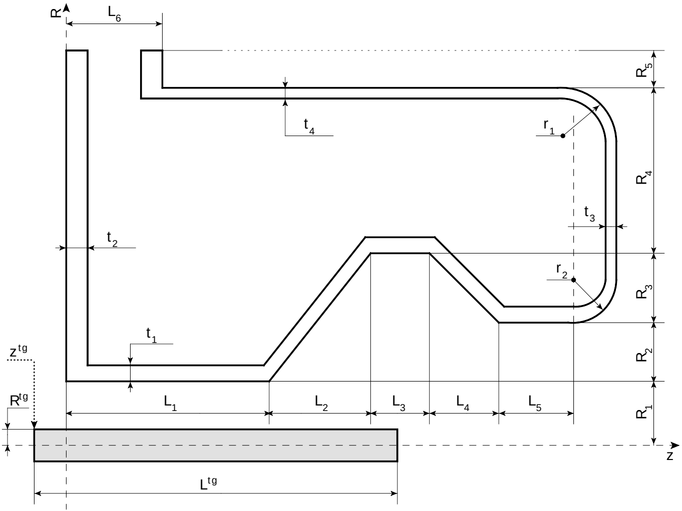
still preliminary result - crude scan over parameter space, larger values of $L_{1,2}$ and $R_{2,3}$ might even better, use α instead of R_2

REOPTIMISING NUFACT HORN (III)



3σ discovery of non-zero $\sin^2(2\theta_{13})$ [in collab with A.Longhin]

Energy deposition – MiniBooNE-like horn



A.Longhin's best of (for $R_2 = 0$ cm):

$E^{kin} = 4.5$ GeV

$L^{tg} = 78$ cm
$R^{tg} = 1.5$ cm
$z^{tg} = 0$ cm

$L_1 = 62.5$ cm
$L_2 = 63.9$ cm
$L_3 = 10.8$ cm
$L_4 = 16.0$ cm
$L_5 = 8.0$ cm
$L_6 = 3.0$ cm
$L_{\rm tot} = 168.4$ cm

$R_1 = 4.0$ cm
$R_3 = 12.0$ cm
$R_4 = 4.0$ cm
$R_1 + R_3 + R_4 = 20.0$ cm
$R_5 = 2$ cm

$r_1 = 5.1$ cm
$r_2 = 7.2$ cm

$t_{1,2,3,4} = 10$ mm

$I = 300$ kA

No reflector here...

Perhaps Andrea can reoptimise for $R_2 \neq 0$ cm?!

ENERGY DEPOSITION

Remember, that at 4 MW and 50 Hz for $E = 4.5$ GeV ...

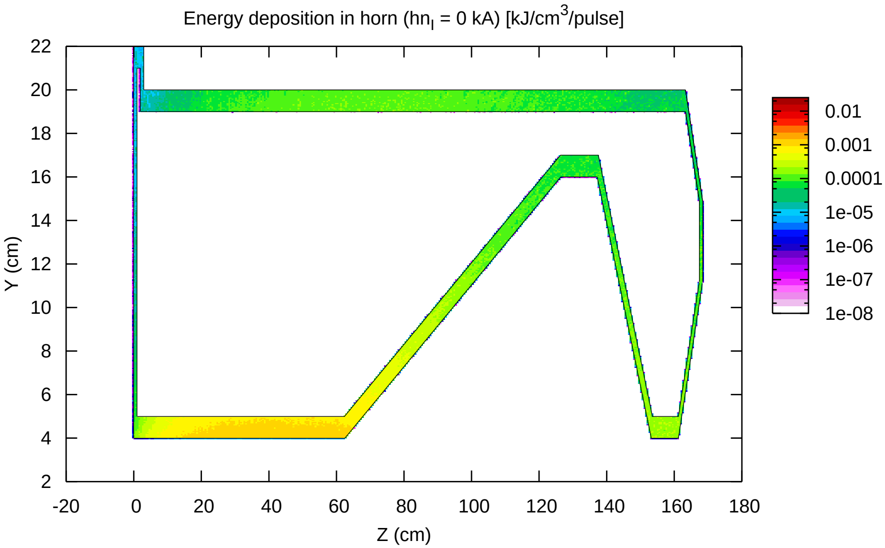
... 0.56×10^{16} p.o.t/s and 1.11×10^{14} p.o.t/pulse

Horn material in simulation: *Aluminium*

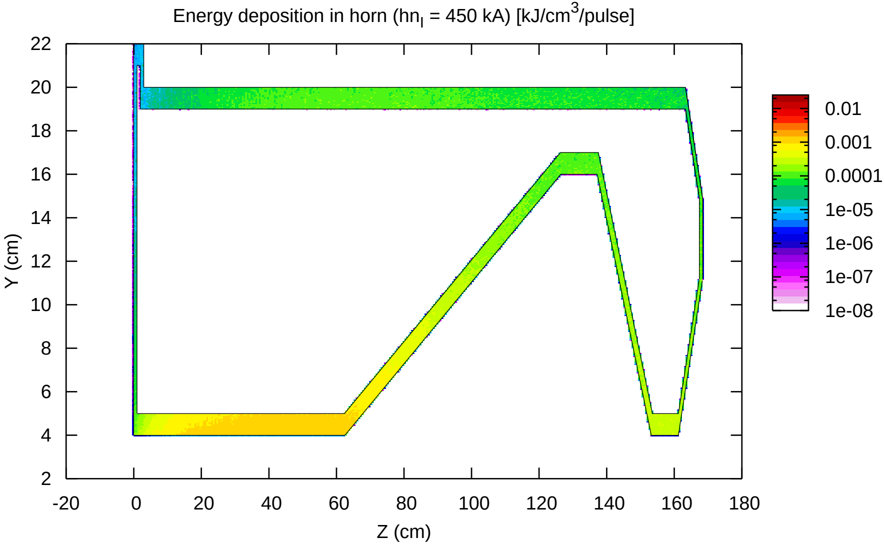
Horn thickness: 1 cm

Too thick??? – Perhaps, but NuFact prototype had upto 6 mm + 2 mm skin thickness due to double-layer design for inner conductor - along the conic section dropping to 3 mm + 2 mm.

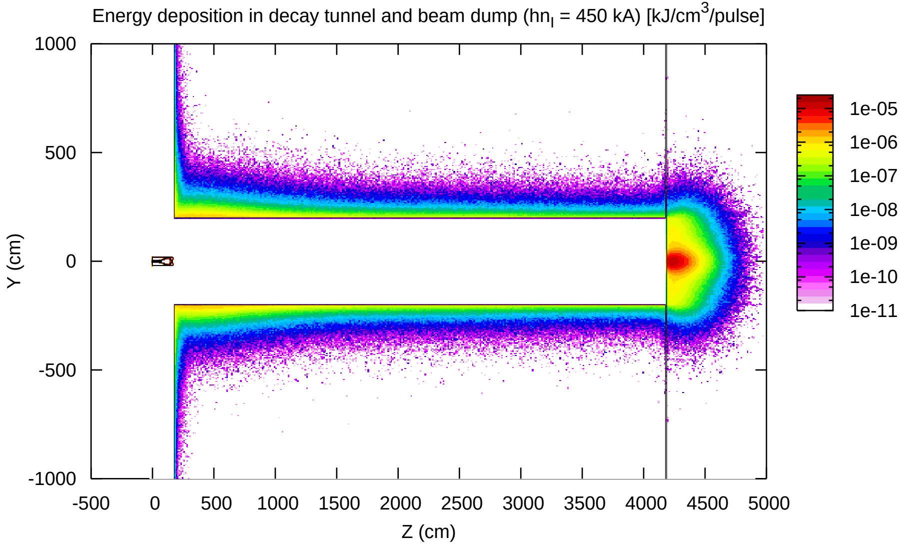
ENERGY DEPOSITION – $I = 0$ kA



Energy deposition – $I = 450$ kA



TARGET + HORN + DECAY TUNNEL + BEAM DUMP – $I = 450$ KA



TOTAL ENERGY DEPOSITION

Power [kW]	$I = 0$ kA	$I = 450$ kA
target	202	203
horn	140	154
decay tunnel	2291	2161
beam dump	653	765
sum	3285	3283

DECAY TUNNEL = Molasse (CNGS studies CERN-OPEN-2006-009)
mass fractions:
53.9 % O, 29.4 % Si, 12.2 % Ca, 3.67 % C, 0.73 % H

dimensions:
$L = 40$ m, $R = 2$ m

BEAM DUMP = C ($\rho = 1.85$ g/cm^3)

horn focusing shuffles $\sim$ 110 kW from decay tunnel into beam dump and increases energy deposition in horn by 10 %