HORN STUDIES FOR SPL-SUPERBEAM

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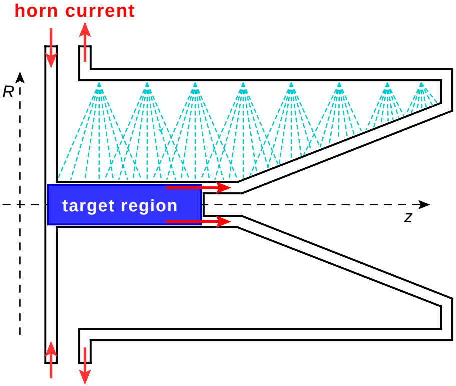
Phone meeting – 15th April 2010

Outline

- Energy deposition in target
  ⇒ Study of integrated target as inner horn conductor
  (work in progress with Gérard Gaudiot and Benjamin Lepers)
- Shape optimisation
  ⇒ NuFact-horn

Integrated target energy deposition

INTEGRATED TARGET



Idea put forward by Chris Densham:

Integrate the target as inner conductor inside the horn

Requirement

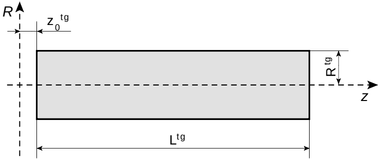
- conducting target material

Advantages

- lower inner radius $\rightarrow$ higher magnetic field or lower horn current
- can use water cooling of inner horn conductor also for target cooling

TARGET & BEAM - PARAMETERS

GEOMETRY target length $L^{tg} = 78$ cm and radius $R^{tg} = 15$ mm



MATERIAL target: low-Z materials: Beryllium, Aluminium, AlBeMet, comparing to Carbon – high-Z materials perhaps interesting too, but give more neutrons

BEAM proton beam,
kinetic energy $E^{bm}_{\rm kin} = 4.5$ GeV,
beam power 4 MW,
frequency 50 Hz,
pulse duration $\lesssim 5\ \mu$s
gaussian beam profile $\sigma^{bm} = \{2, 4, 6\}$ mm

ENERGY DEPOSITION

Neglecting pulsed structure of beam = assuming continious energy deposition of proton beam @ 4 MW and $E_{\text{kin}}^{bm} = 4.5$ GeV.

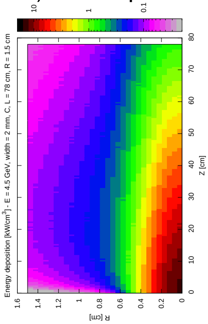
material	density [g/cm^3]	σ^{bm} [mm]	max value power density [kW/cm^3]	total power [kW]
Be	1.85	2	11.65	168.7
		4	3.25	165.3
		6	1.53	153.2
C	1.85	2	13.22	200.0
		4	3.57	196.5
		6	1.72	182.2
Al	2.70	2	19.26	285.6
		4	5.36	279.1
		6	2.73	257.4
AlBeMet (Be 61%, Al 38%, O 1%)	2.1	2	14.11	204.4
		4	3.92	200.1
		6	1.86	185.2

The maximal value of deposited power density and the total power deposited in the target at different values of the beam width.

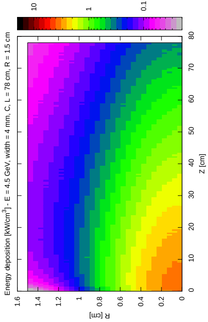
Divide by 4 in the case of 4 target-horn stations.

ENERGY DEPOSITION - DISTRIBUTION

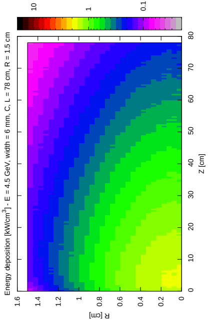
... in 1) $z - R$ plane and 2) R for fixed values of z



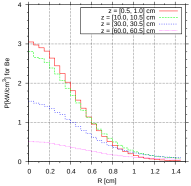
C-target $\sigma^{bm} = 2$ mm



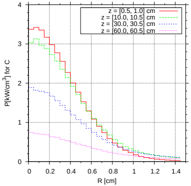
C-target $\sigma^{bm} = 4$ mm



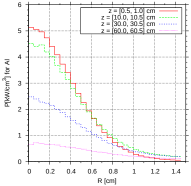
C-target $\sigma^{bm} = 6$ mm



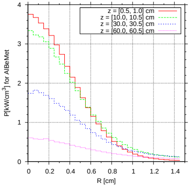
Be



C



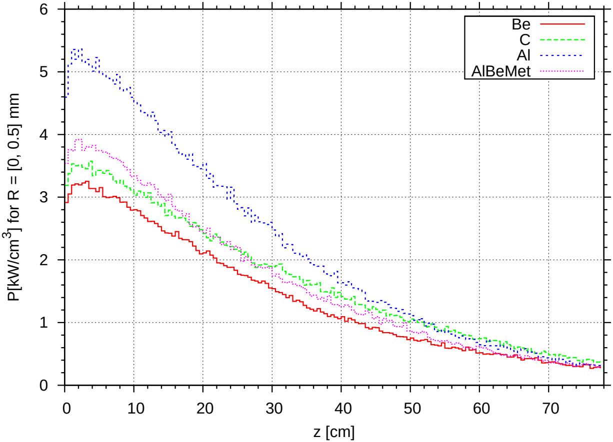
Al



AlBeMet

ENERGY DEPOSITION - DISTRIBUTION

... in 3) for z and fixed $R \in [0.0, 0.5]$ mm = along "z-axis"



... to be continued with first estimates of final temperature by Benjamin Lepers

Shape optimisation NuFact-horn

HORN – SHAPE OPTIMISATION

... various ideas

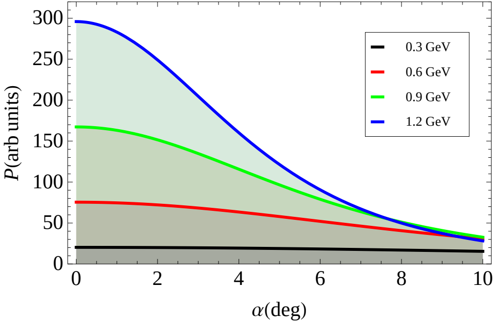
PROBLEM: A GOOD CRITERIA FOR OPTIMISATION

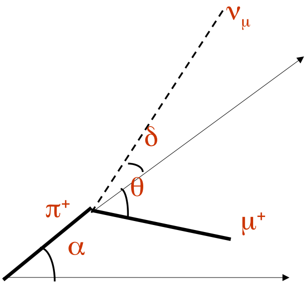
- sensitivity of physics parameters (θ_{13}, δ_{CP}), BUT requires full simulation and also details on detector
- optimise ν spectrum in solid angle corresponding to detector $\rightarrow$ still too time consuming, requires full simulation of target, horn, decay tunnel and beam dump
- optimise π spectrum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

. . . OPTIMISE π SPECTRUM AFER EXITING HORN

- Using simple numerical Euler-integr. for fast π tracking through magnetic field
- Checked agreement with FLUKA, accuracy depends on stepwidth = compromise for smaller CPU time
- Could be improved using symplectic integr. algorithm. Has somebody experience? Suggestions and help are welcome.

π DECAY KINEMATICS





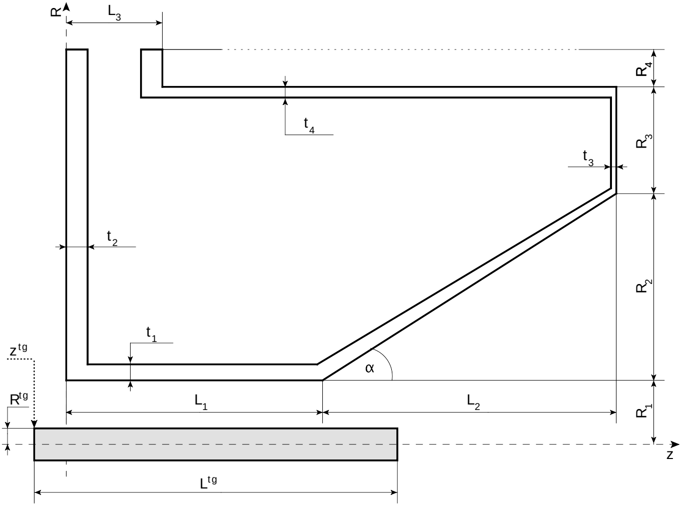
Probability of ν_μ hitting detector depends on π-momentum and angle ($\delta = -\alpha$)
$\rightarrow$ more important to focus π's with large momentum

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

Accept π as "good" (or "background" for opposite charge), if α such that

$$P(\alpha) > 1/2 \times P(0)$$

- 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
$R_4 = 4$ cm
$t_{1,2,3,4} = 3$ mm

varying:

$z_0^{hn} \in [-20, 20]$ cm,
$L_1 \in [50, 150]$ cm,
$L_2 \in [50, 150]$ cm,
$R_1 \in [1.2, 6.0]$ cm,
$\alpha \in [2, 30]^\circ$,
$R_3 \in [4, 10]$ cm,
$I \in [100, 300]$ kA

Campagne/Cazes:

$L_1 = 40$ cm,
$L_2 = 100$ cm,
$R_1 = 3.7$ cm,
$R_2 = 12.6$ cm,
$R_3 = 4$ cm

REOPTIMISING NUFACT HORN - SCAN

- use π sample generated with FLUKA for C-target 10^6 pot
  yielding 759914 π^+ and 498397 π^- at target exit (position, momentum)
- optimise horn for π^- focusing, since background suppression
  more important for $\bar{\nu}_\mu$-run
- look for optimal ratio

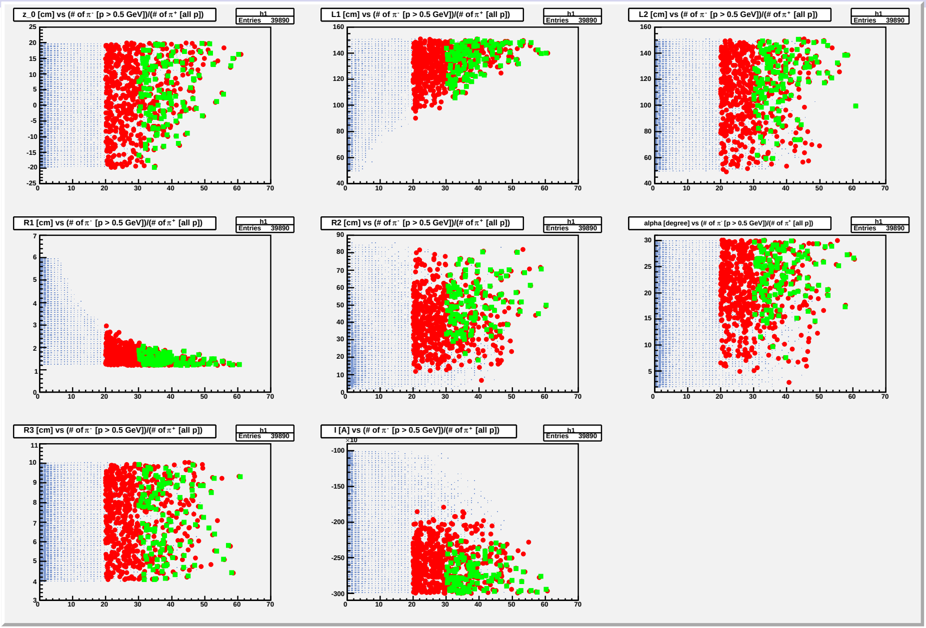
  $R(\pi^-/\pi^+) =$ (# of "good" π^- with $p \in [0.5, 0.7]$ GeV)/(# of "background" π^+)

  π's are counted when exiting the horn within a circular plane of $R = 1$ m
- selection in plots:

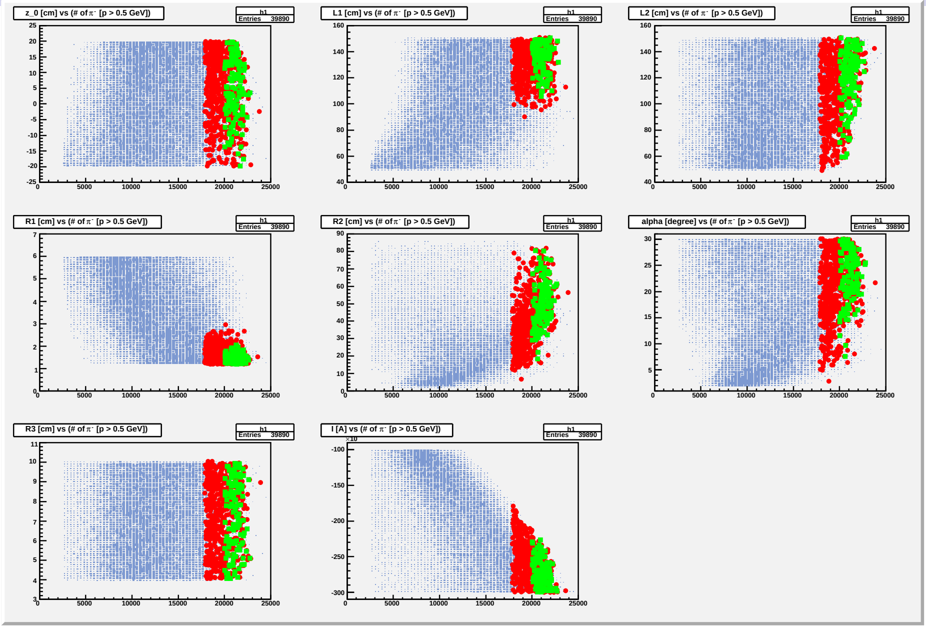
  red = ($R(\pi^-/\pi^+) < 20$) && ($18000 <$ # of "good" π^- with $p \in [0.5, 0.7]$ GeV)

  green = ($R(\pi^-/\pi^+) < 30$) && ($20000 <$ # of "good" π^- with $p \in [0.5, 0.7]$ GeV)
- sample contains 116689 π^+ and 77392 π^- with $p \in [0.5, 0.7]$ GeV

PARAMETERS VS $R(\pi^-/\pi^+)$



PARAMETERS VS (# OF "GOOD" π^- WITH $p > 0.5$ GEV)



"BEST" 13 HORNS

z_0^{hn} [cm]	L_1 [cm]	L_2 [cm]	R_1 [cm]	R_2 [cm]	R_3 [cm]	I [A]	$R(\pi^-/\pi^+)$	# of π^-	# of π^+
9.5	132.9	148.9	1.22	38.8	8.9	-290363	48.1	20832	433
16.6	149.5	136.2	1.60	65.6	7.8	-260182	48.5	20849	430
19.8	140.4	125.0	1.45	70.4	8.8	-284804	49.3	20359	413
-3.17	147.0	133.0	1.20	51.8	7.3	-252144	49.7	21316	429
16.8	135.6	148.2	1.37	80.7	6.7	-297522	51.1	21277	416
19.5	132.5	118.4	1.23	57.6	8.5	-265272	51.9	20147	388
13.0	149.5	124.4	1.46	46.4	9.2	-284583	52.2	21002	402
13.1	145.7	145.3	1.43	52.0	6.4	-295798	52.3	21667	414
1.31	148.9	122.2	1.24	68.5	5.5	-270165	54.0	21269	394
4.21	147.2	131.4	1.31	61.7	5.1	-294389	55.0	22608	411
12.6	142.4	139.2	1.22	43.9	5.8	-297794	57.8	20984	363
15.0	140.4	138.3	1.20	71.6	4.4	-278077	58.9	21142	359
15.8	141.0	98.34	1.22	49.3	9.3	-296638	60.2	21369	355
0.0	40.0	100.0	3.70	12.6	4.0	-300000	0.7	12979	17402

last line: Campagne/Cazes (no reflector), optimised for $p = 600$ MeV and Hg target $L = 30$ cm

Horns become large $L \sim 3$ m and $R \sim (0.5 \ldots 1)$ m – even larger?

To be done:

- check stabilitiy of results for small parameter variations
- check final $\sin^2(2\theta_{13})$ and δ_{CP} sensitivities
- check material effects (horn, decay tunnel)

"Best" 13 horns