LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

J.E Campagne

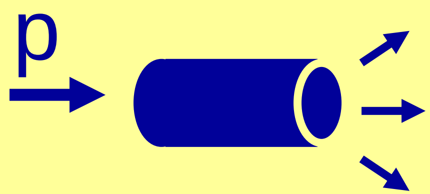
SPL-Fréjus

Collection part

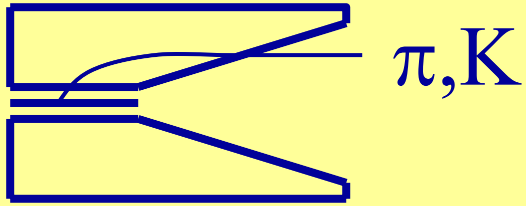
Thanks to S. Gilardoni, A. Cazes

New optimization questioned @ MMW04*

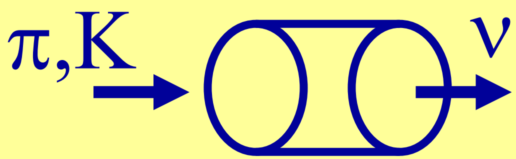
Particle production



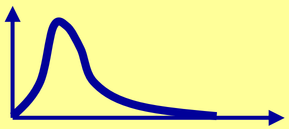
Horn design optimisation



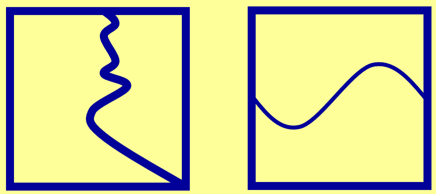
Decay tunnel parameter optimisation



Flux computation at Fréjus



θ_{13} and δ_{CP} sensitivity.



LAL – 04-102 submitted to EPJC

*: Multi MegaWatt Workshop at CERN 26-28 May 04

Particle production

Proton beam :

1. Pencil like
2. E_k=**2.2GeV**, **3.5GeV**,…, 8GeV

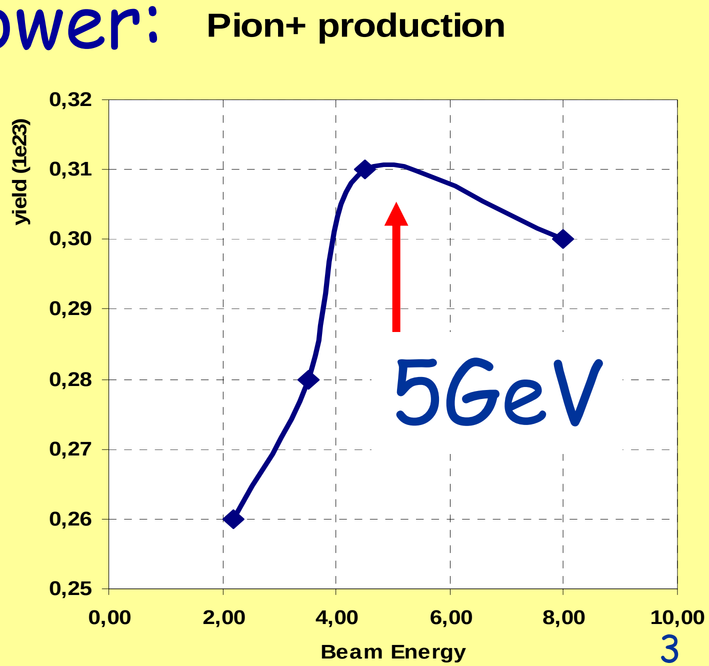
Target :

1. 30cm long cylinder, ∅15mm in Liq. Hg
2. FLUKA 2002.4

Normalized to 4MW beam power:

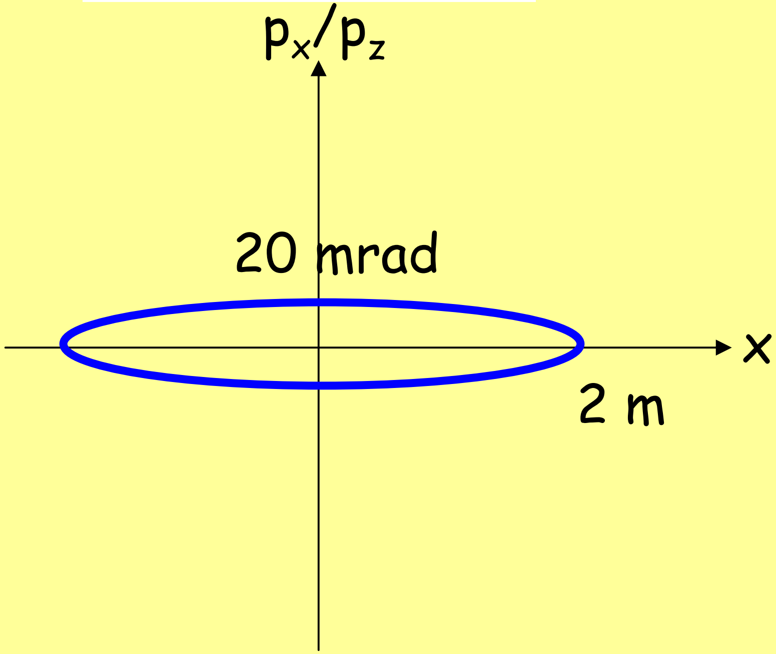
1.10 10^{23} pot/yr @ 2.2GeV
0.69 10^{23} pot/yr @ 3.5GeV
0.30 10^{23} pot/yr @ 8.0GeV

Max. π yield
≠
Max. Phys. sensitivity



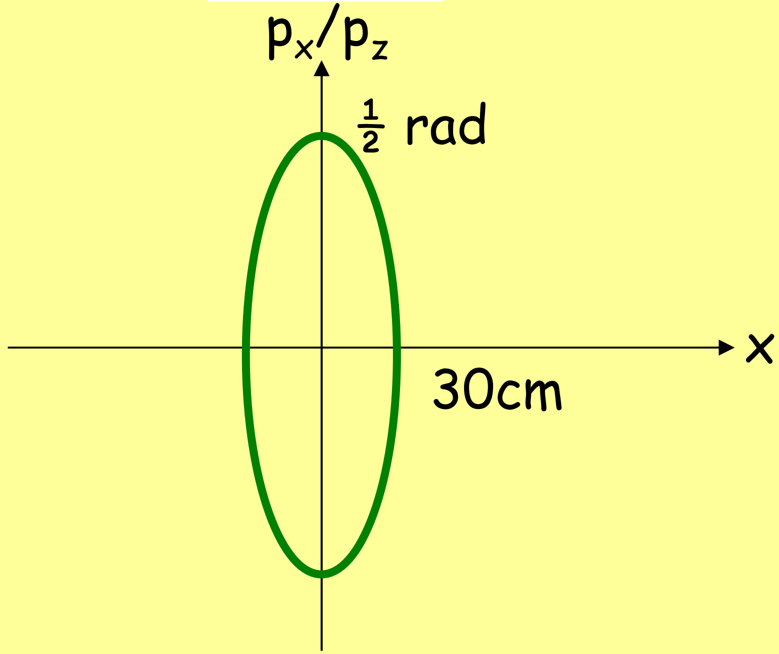
SuperBeam vs νFact Optics

Super Beam



Spot size @ 130km
Decay tunnel size

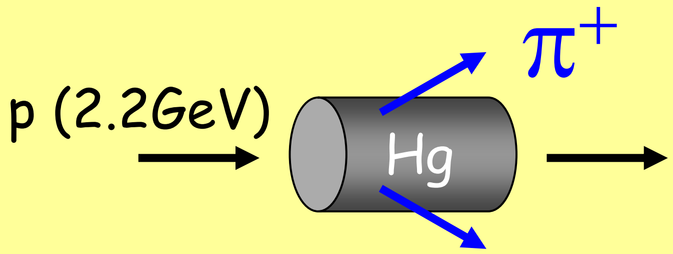
νFact



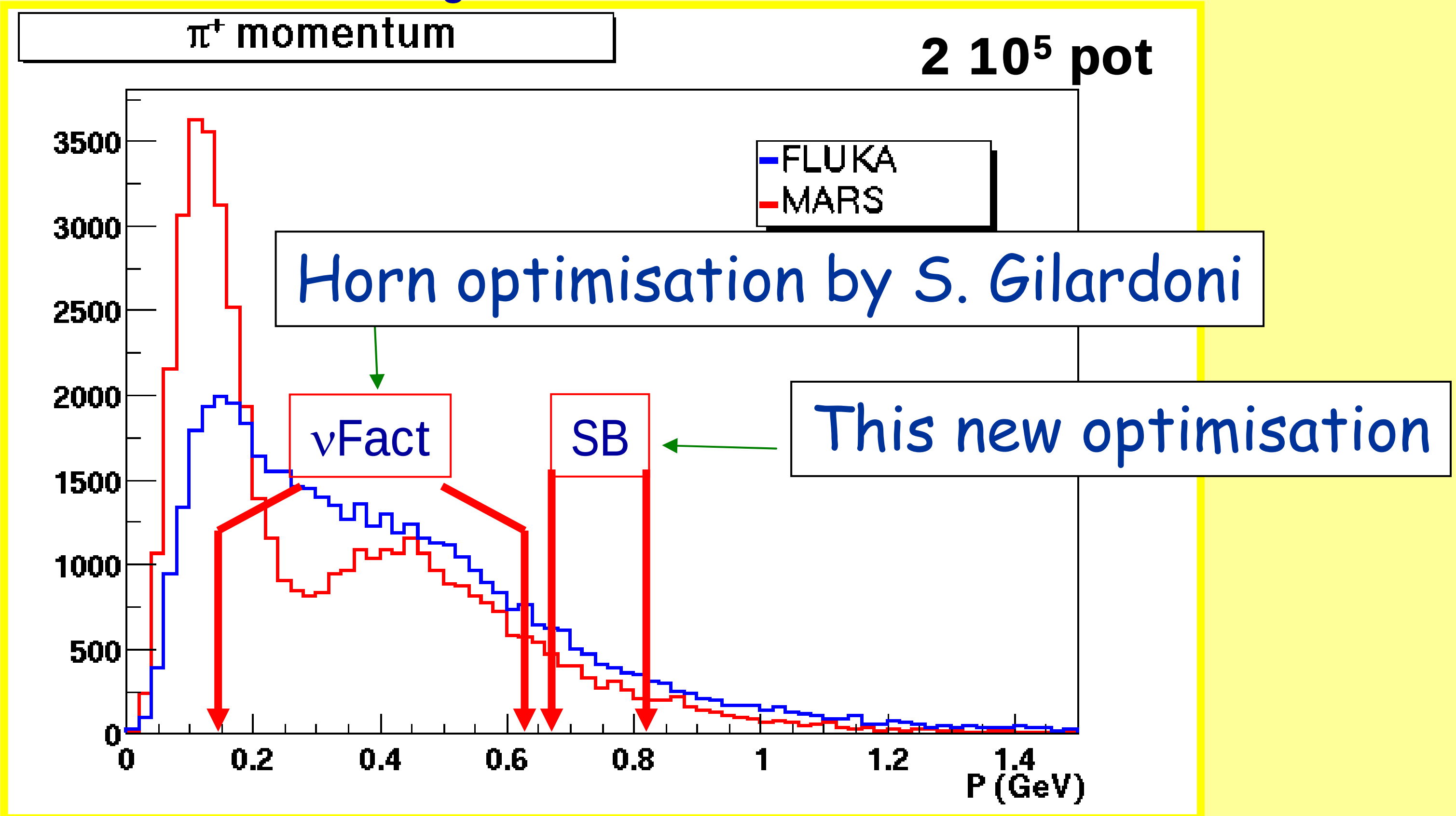
Decay channel solenoids
Aperture and B strength

Thanks S. Gilardoni

Pion production



at the exit of the target



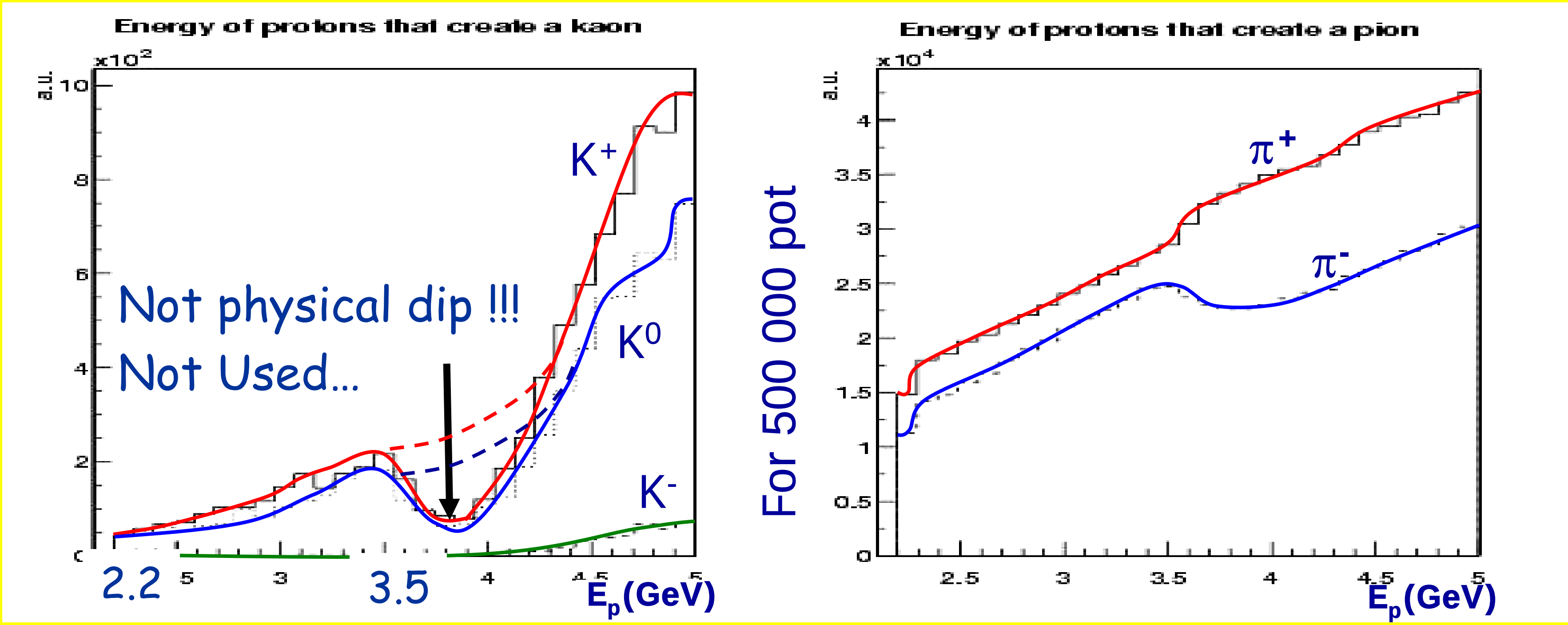
Rule of thumb: $E_\pi/3 \sim E_\nu$ (MeV) > 2.L(km)

Kaon production?

New Fluka will be tested

HARP ???

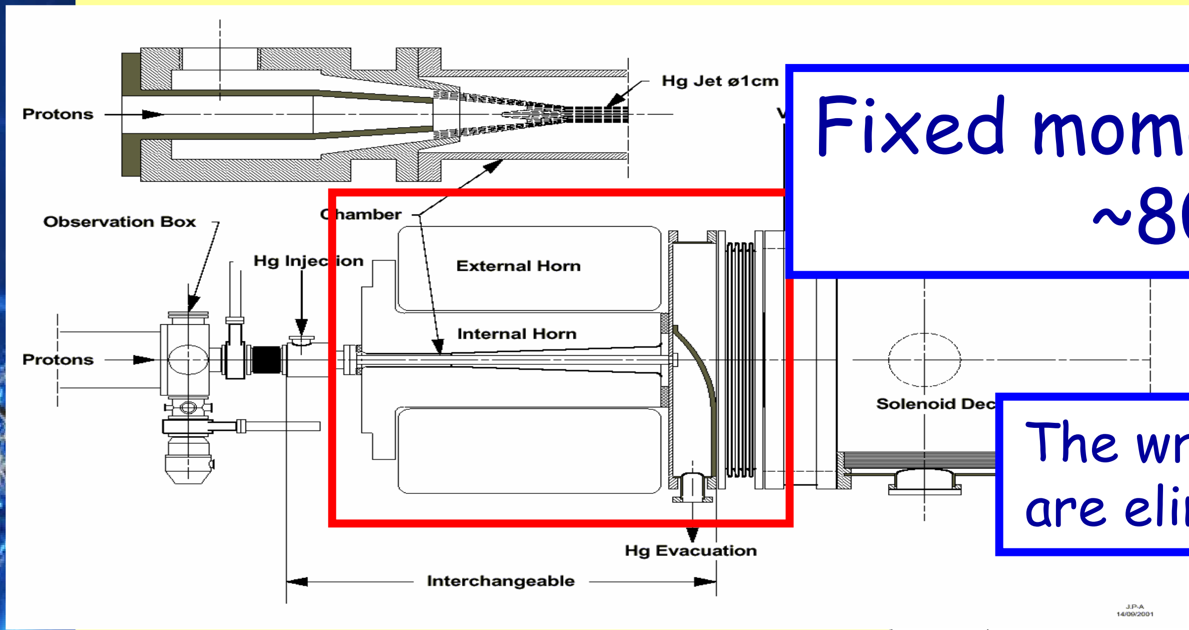
see BENE meeting 11/09/03



Rate x 10^{16}

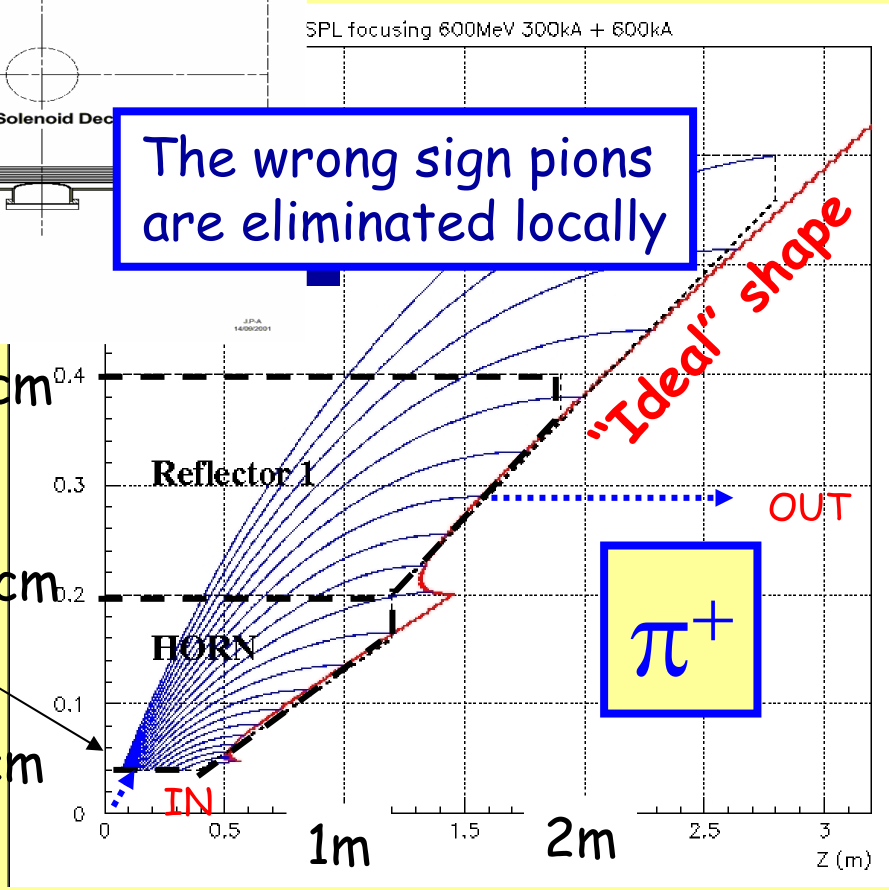
- at 2.2GeV :
  - 0.26 π^+/s
  - 0.8 10^{-3} K^+/s
- at 3.5GeV :
  - 0.29 π^+/s
  - 2.8 10^{-3} K^+/s
- at 4.5GeV :
  - 0.32 π^+/s
  - 5.2 10^{-3} K^+/s

Horn style of collection



Fixed momentum focalisation ~800 MeV/c

The wrong sign pions are eliminated locally



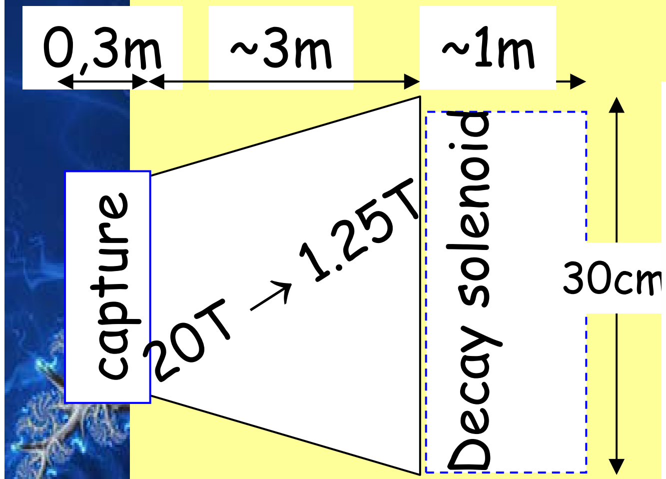
$B_\phi(r) \propto I_{cur}/r$

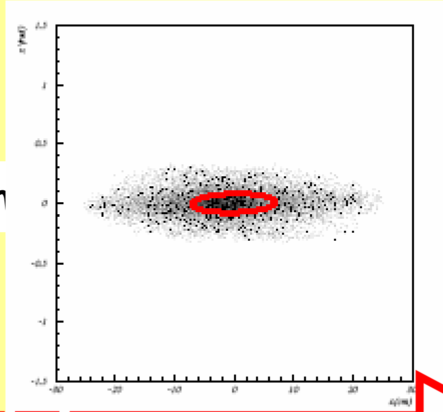
$I_{cur} \sim (300 \div 600)$ kA

r_{min} limited by Target size

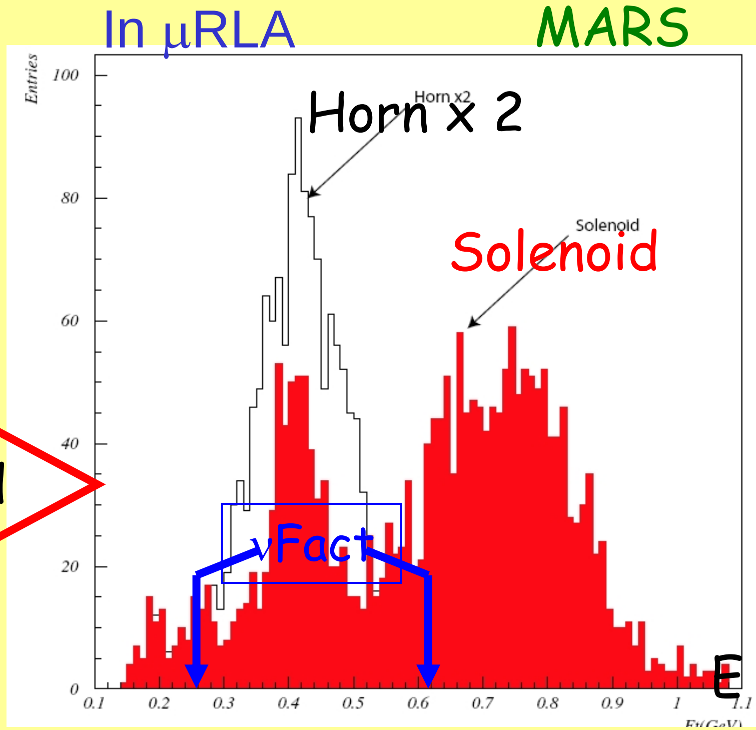
JEC NuFact-Note-138

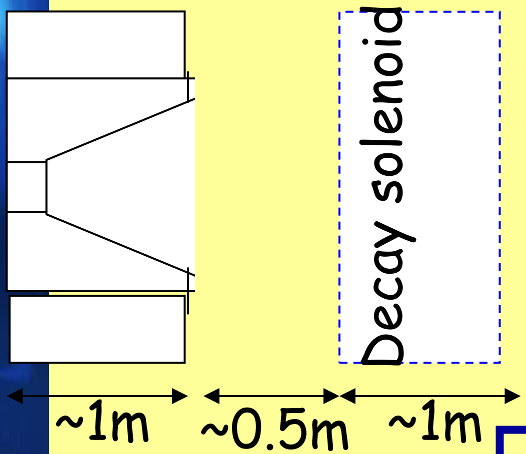
Comparison Solenoid vs Horn

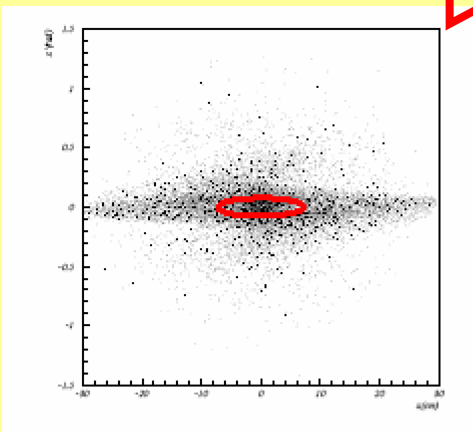




Cut : 1.5 cm.rad







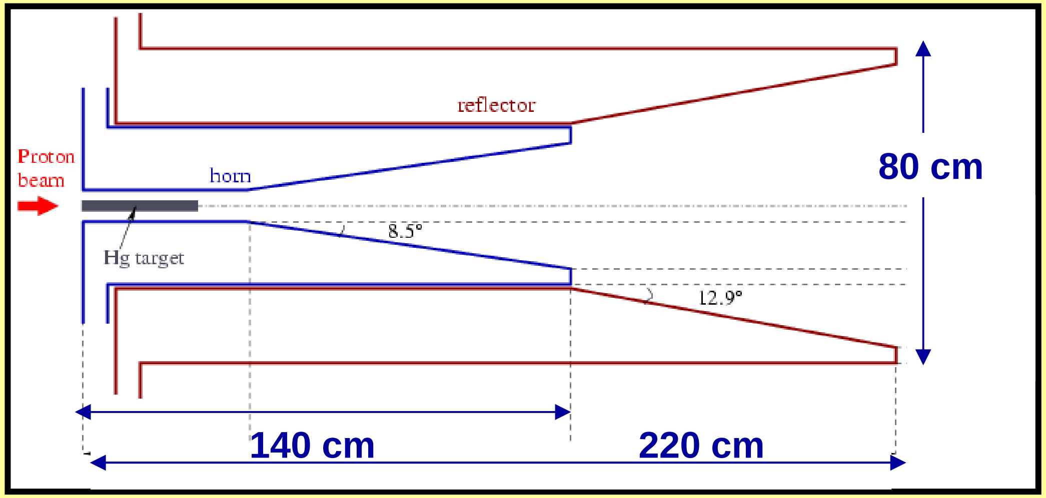
The collection yield is identical ~1.4 10^{-3} π/pot

Horn ≈ Solenoid

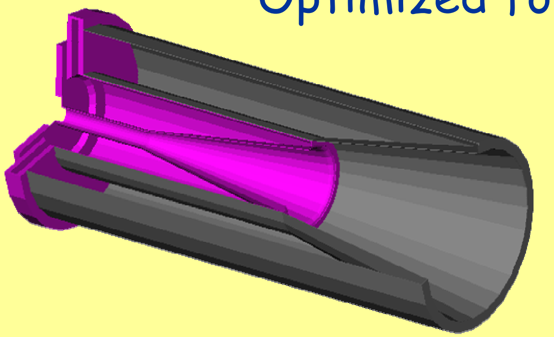
S. Gilardoni thesis

Horn design parameter for Super Beam

Conductor thickness : 3mm
horn : 300kAmps
reflector : 600kAmps
Challenging!!!



Drawing from the horn built at CERN
Optimized for Super Beam



E_ν~300MeV
E_π~800MeV

+ or - focusing

Using Geant 3.2.1
NuFact-Note 138

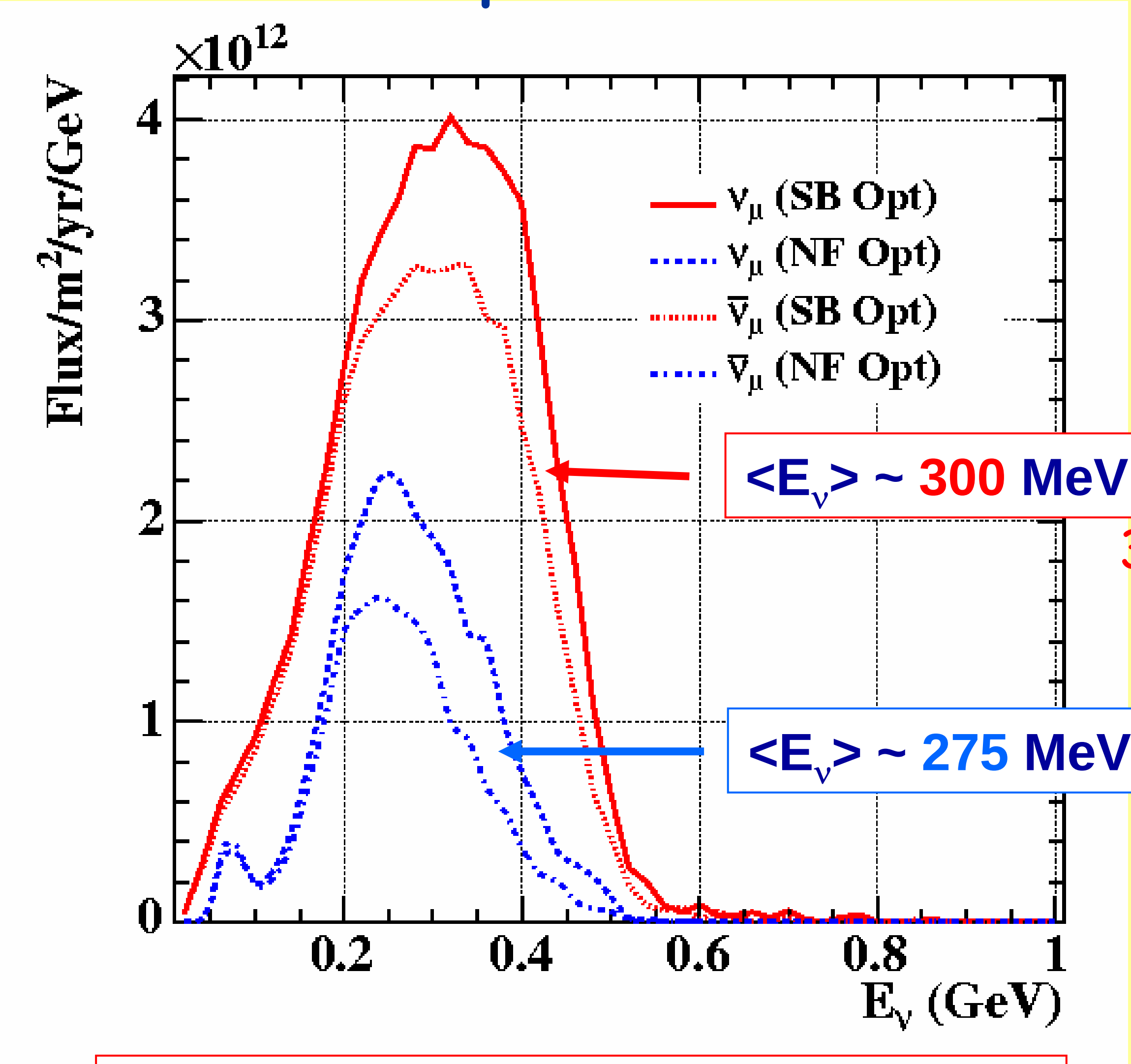
HORN	
inner radius	3.4cm
neck length	40cm
outer radius	20.5cm
total length	140cm
REFLECTOR	
outer radius	40cm
total length	220cm

Decay Tunnel Parameters

- Lengths:
  1. Modify beam purity
  2. Tested: 10m …→ 40m …→ 60m
  3. Optimum @ 40m
- Radius:
  1. modify acceptance
  2. 1m …→ 2m
  3. No optimum found: larger is better (we just keep "reasonable" radius)

This results have been checked on sensitivity to θ_{13} and δ_{CP}

Fluxes comparison @ 130km



~95 ν_μ^{CC}/kT/yr*

$\langle E_\nu \rangle$ ~ 300 MeV, 1.2 10^{12}/m²/yr

3.5GeV SPL optimum

$\langle E_\nu \rangle$ ~ 275 MeV, 4.5 10^{11}/m²/yr

Old νFact optimum

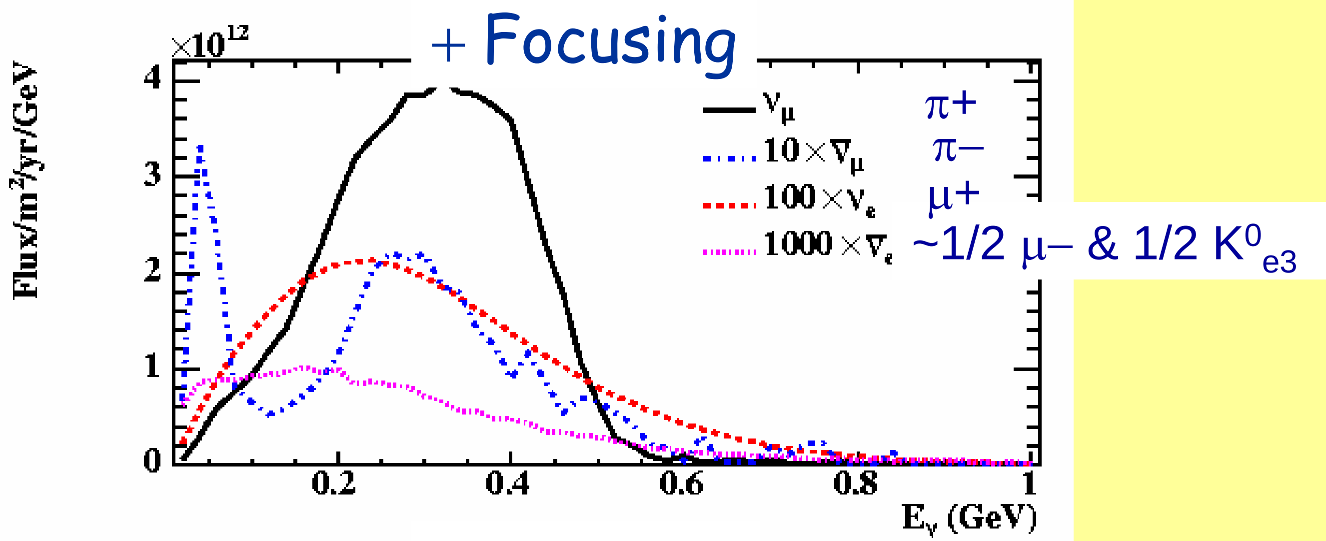
Reflector: 50% of the Flux

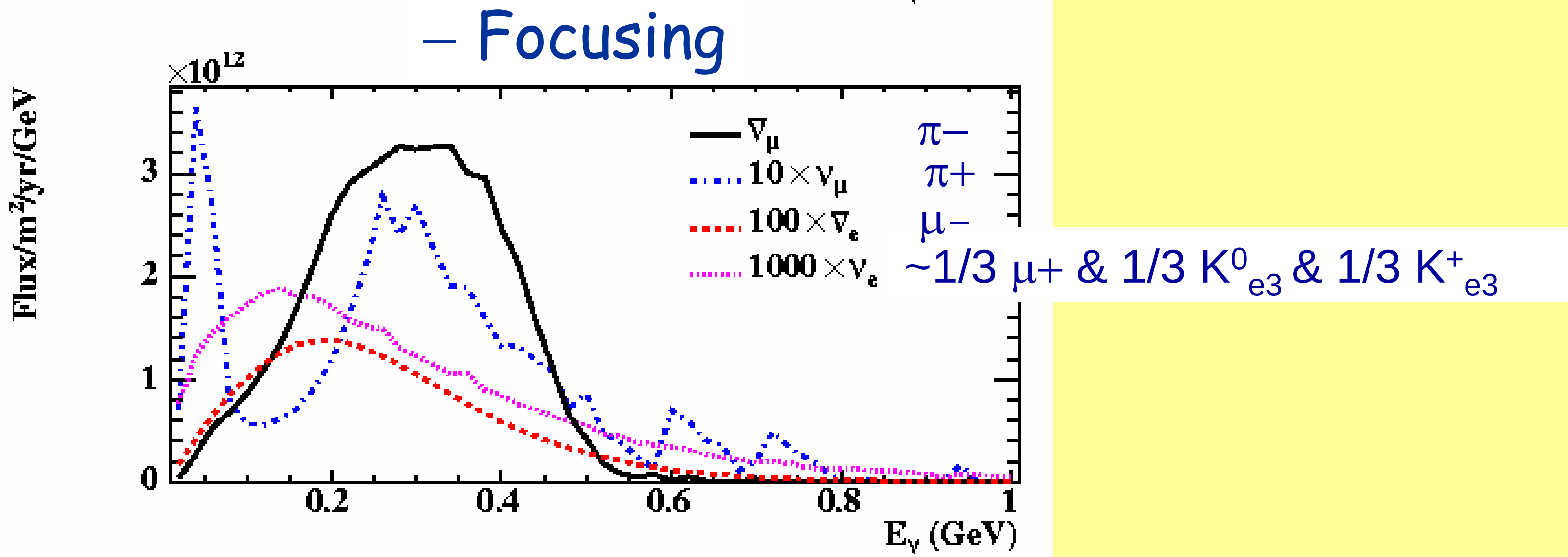
*: Lipari x-sect. (see later)

Flux @ 130km: composition

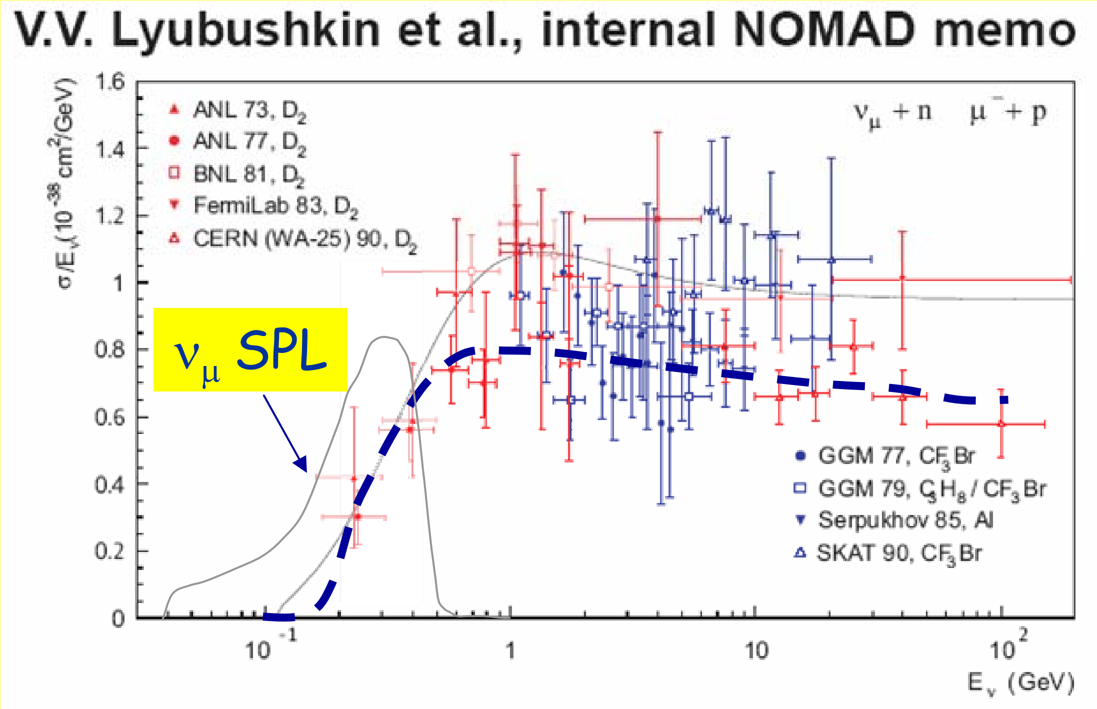
http://opera.web.lal.in2p3.fr/horn/Simu/index.htm

3.5GeV Kinetic p beam
~800MeVπ focusing
40m decay tunnel length
2m decay tunnel radius





The X-sections



---: Lipari et al.

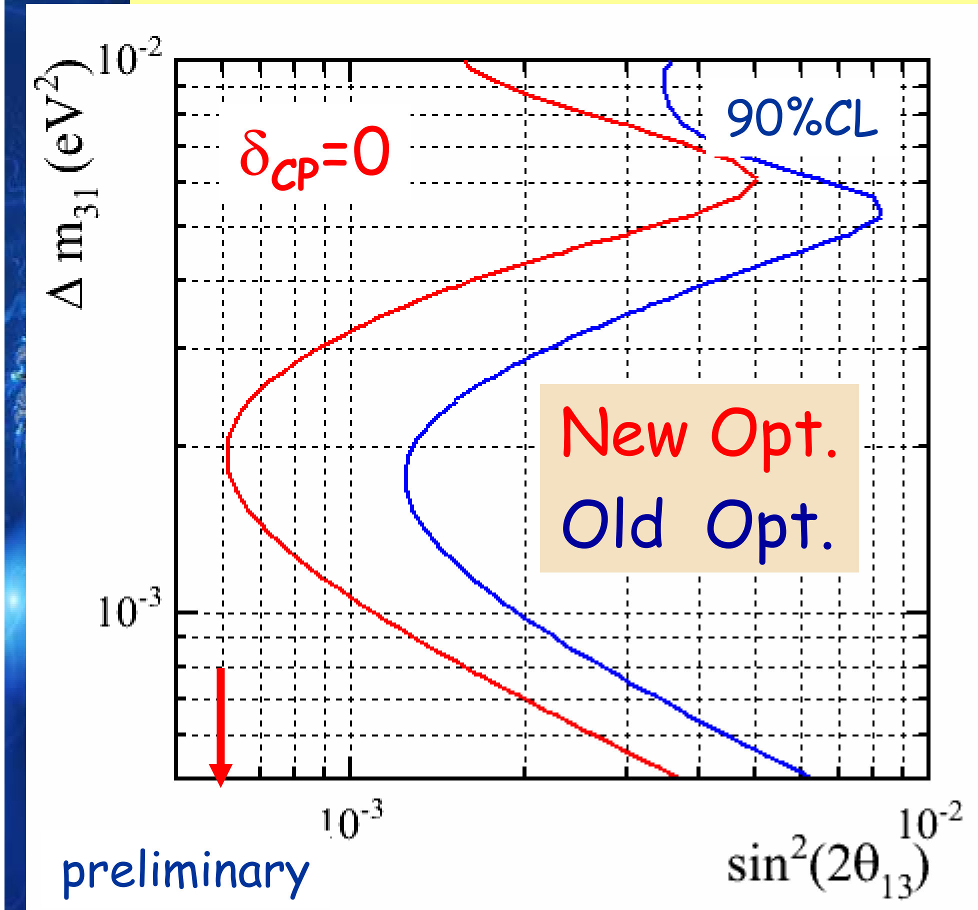
PRL**74**(95)4384

on H_2O

βB is an ideal tool to measure these cross-sections and a 2% systematic error on both signal and background are used.

Some physics performances

440kT water Č, 4MW SPL, GLoBES



5yrs (+)

True values: **(Δm^2_{3}, $\sin^2 2\theta_{13}$)**

$\sin^2 2\theta_{12}$=0.82, $\theta_{23}=\pi/4$, **Δm^2_{21}**=8.1 10^{-5}eV^2

5% external precision on θ_{12} and **Δm^2_{21} and use SPL disappearance channel and spectrum analysis***

2% syst. on signal & bkg

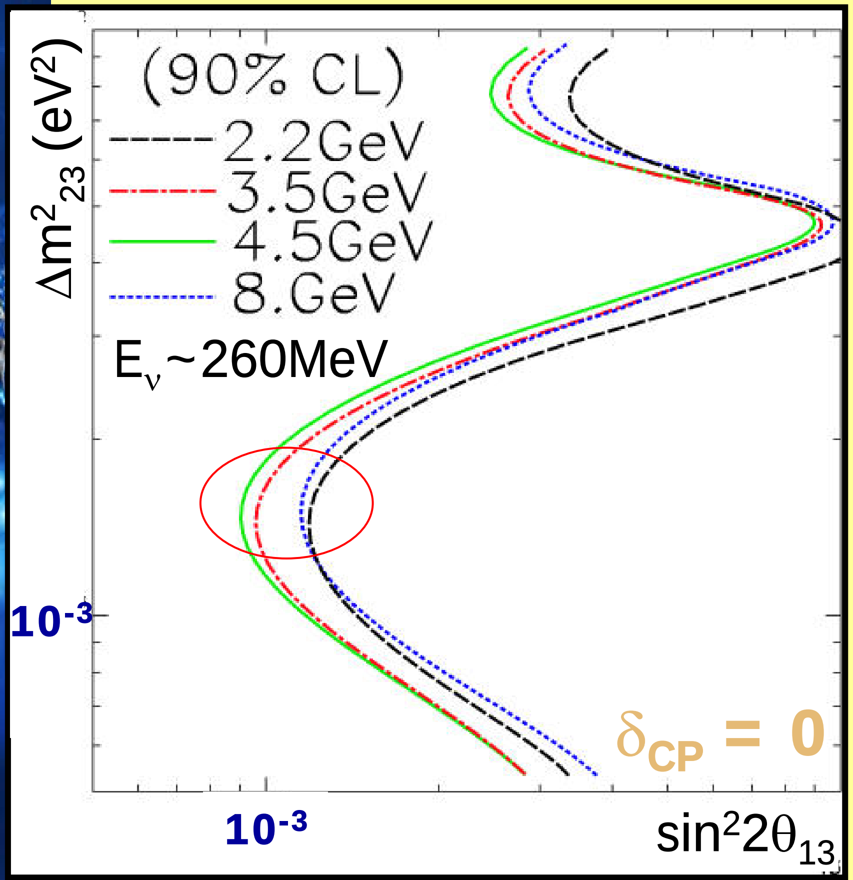
$\sin^2 2\theta_{13}$(90%CL) = 6 10^{-3} (0.7°)

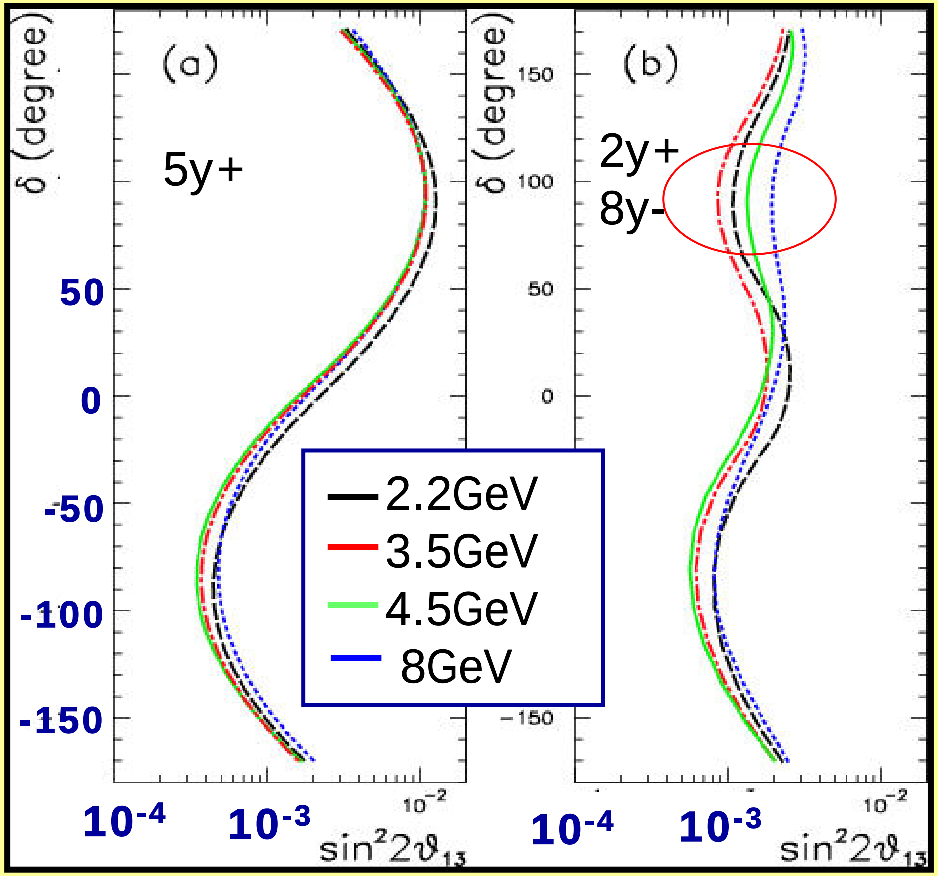
sizeable improvement

*: 5 bins [0.08,1.08] GeV

(χ^2(2dof)=4.6 or 11.83)

Beam Energy comparison

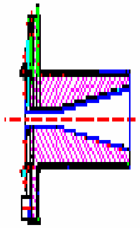




hep-ex/0411062 with an early version of analysis

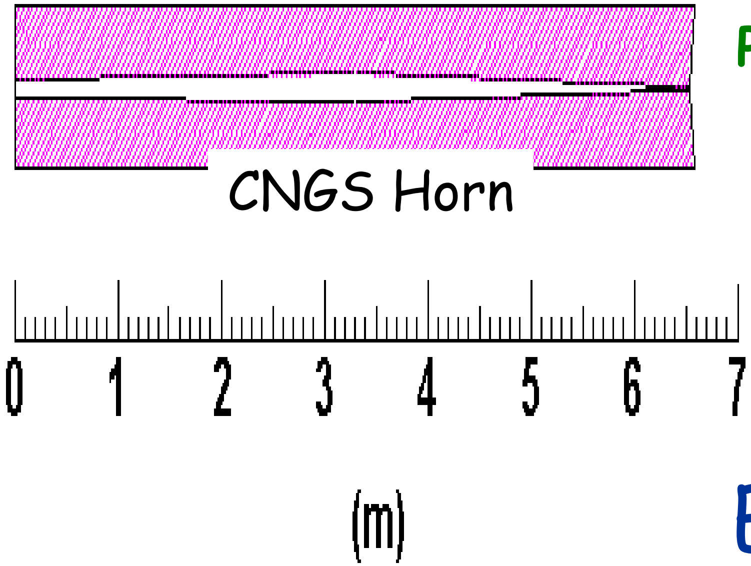
3.5GeV is an optimum

CNGS vs SB/νFact HORN



SB/νFact CERN proto

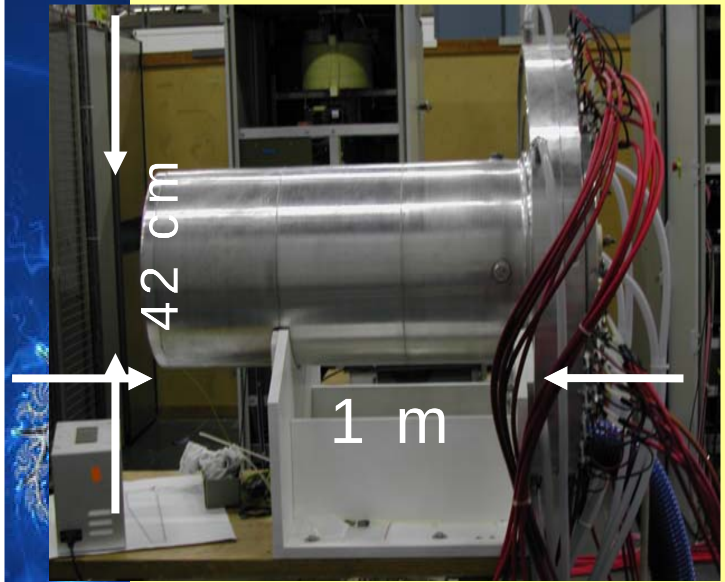
P_{beam} = 4MW / 2÷3GeV, **Target inside**
300÷600kA/50Hz/100μs
200 M pulses/6 weeks
Neck: P_J = 7kW, **P_B = 63kW** (8mm eq. Alu)
10^{22} fast neutron/cm²/6 months

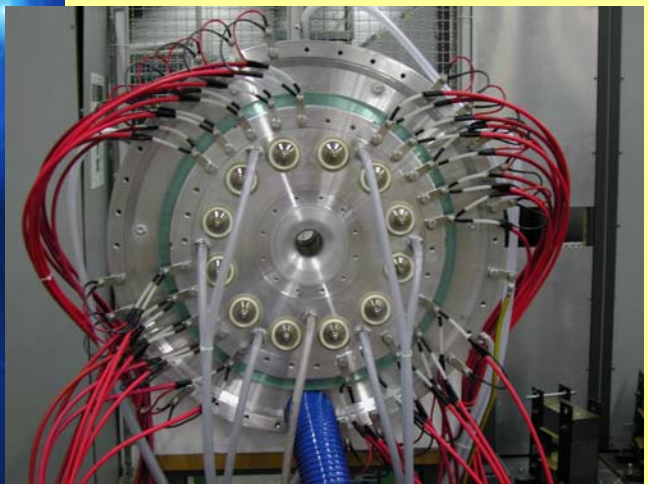


P_{beam} = 0,4MW / 400GeV, **Target outside**
150kA/2pulses 10μs-6s
20 M 2pulses/5 years
IC: **P_J = 13kW**, P_B = 5kW (2mm Alu)

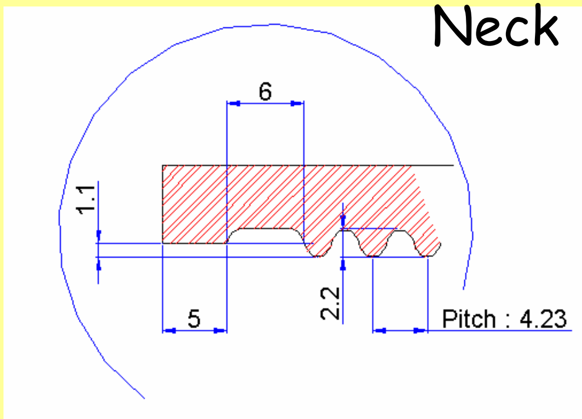
Every parameter is critical

CERN prototype (2001-2002)





Neck

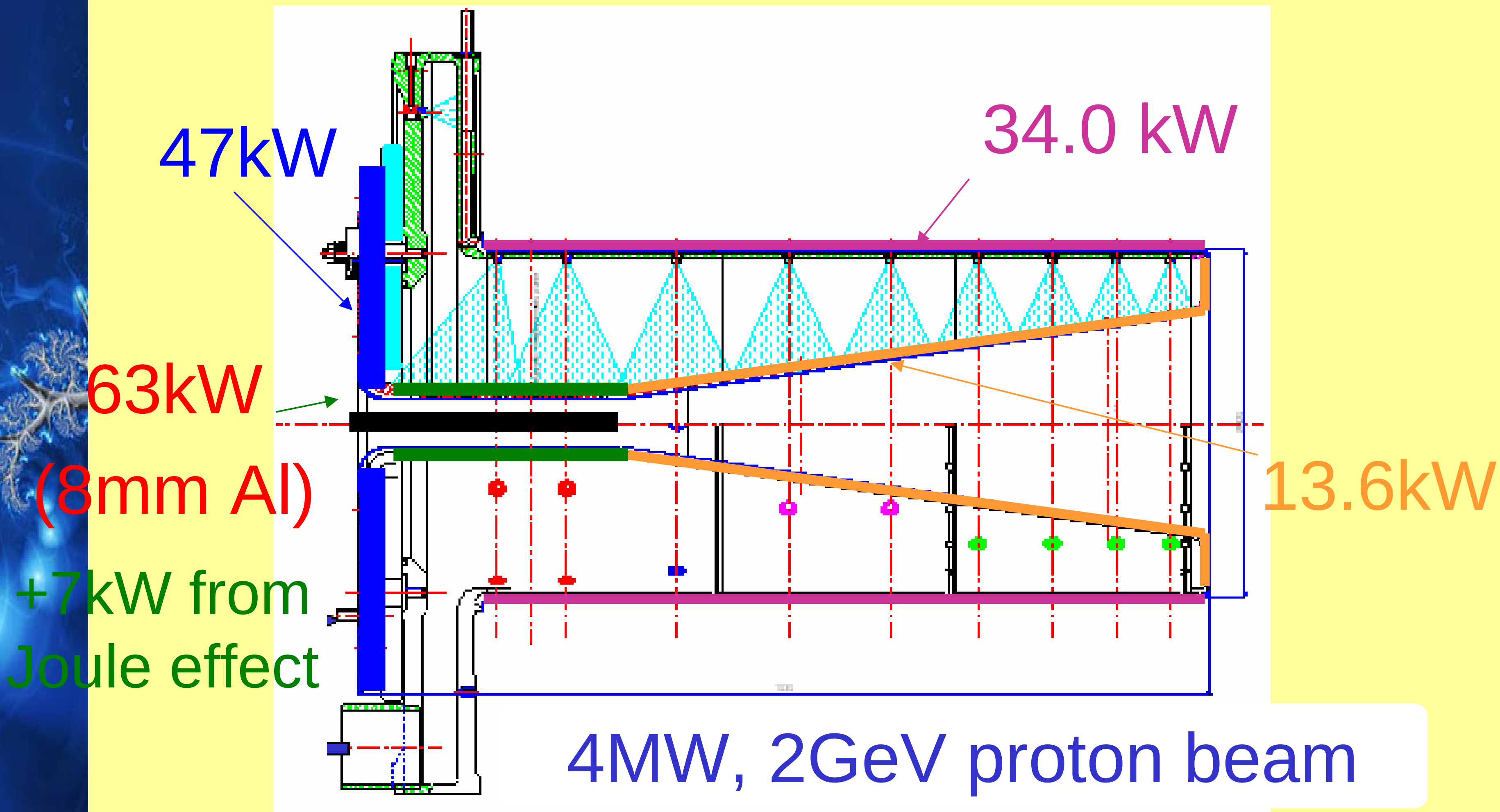


Water cooling

(NUFACT-NOTE : 4, 28, 42, 80, 81, 126, 129)

S. Gilardoni
S.Rangod, J.M Mauguin

Energy deposition in the horn (induced by protons)

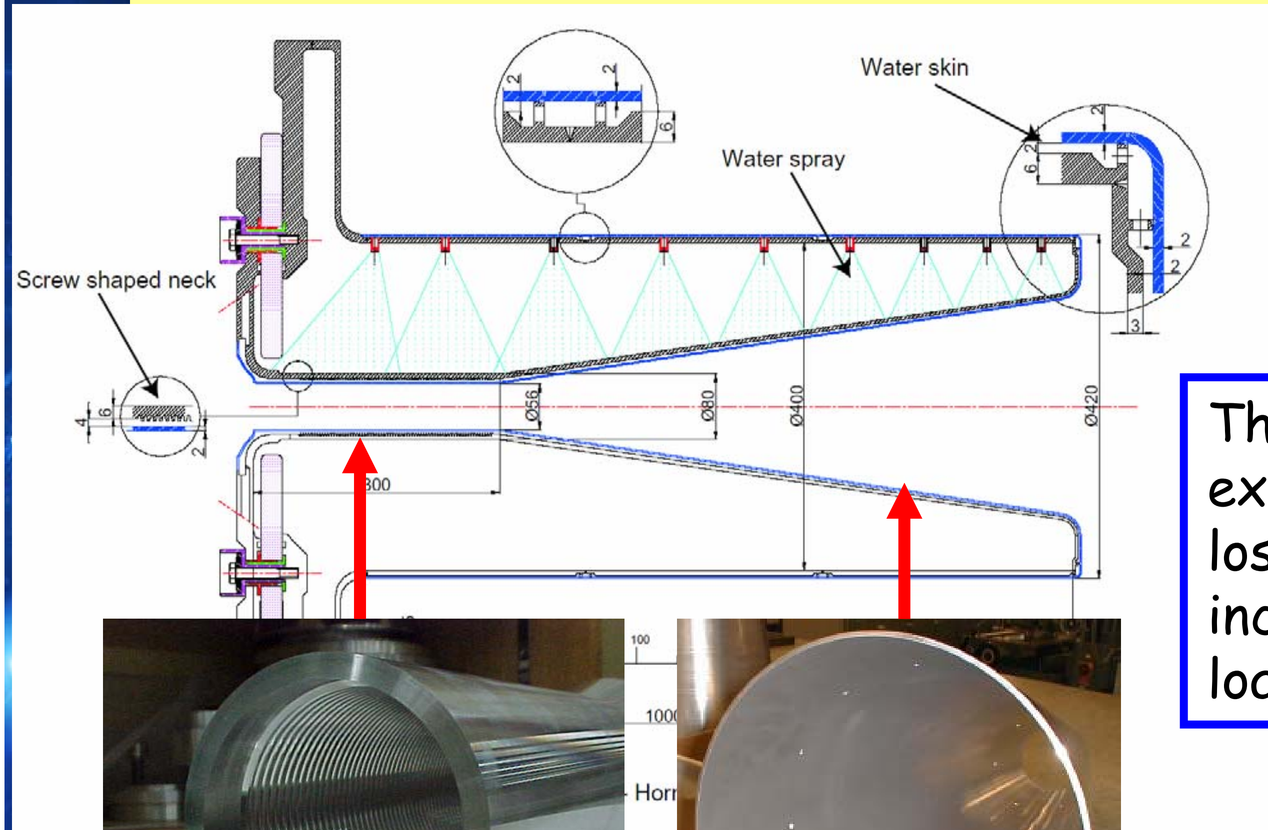


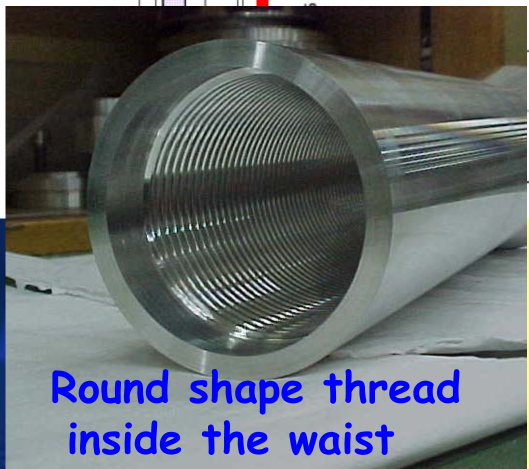
Solution ?: reduce Al thickness (3mm Al) + strength rings

A. Cazes + JEC

Nufact-Note-134

Horn cooling (CERN schema)

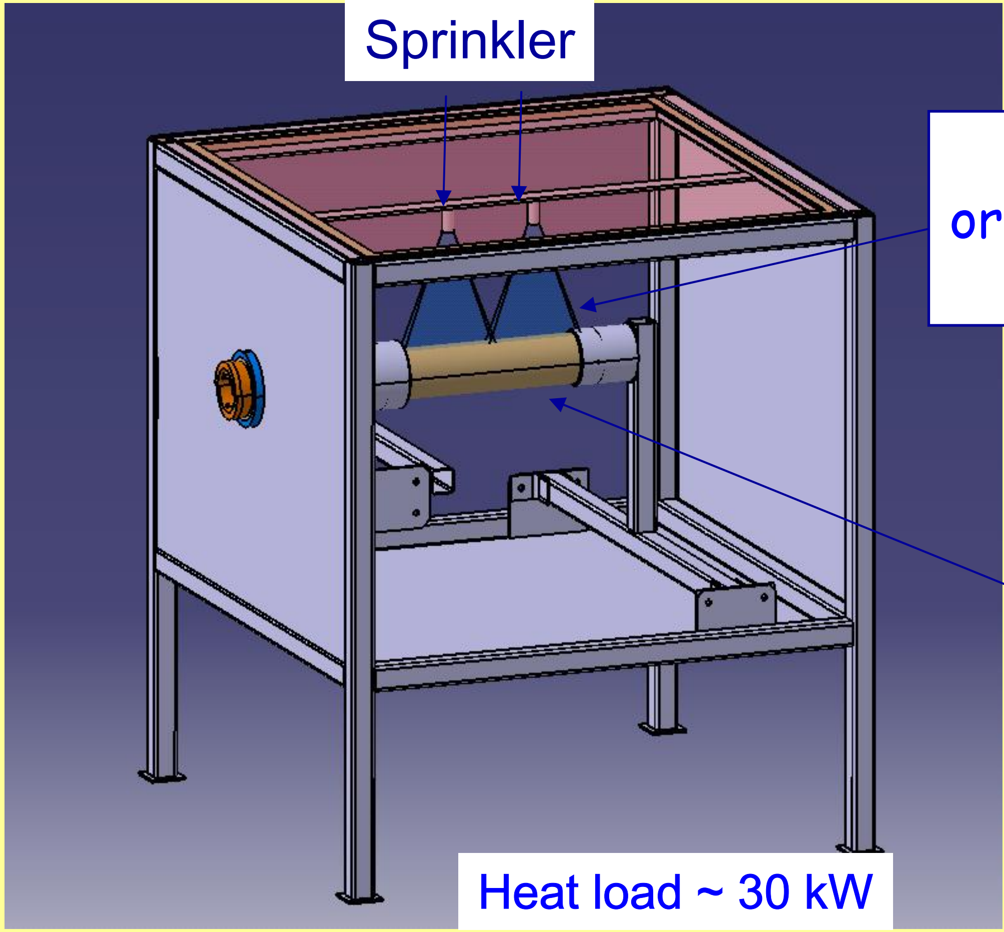




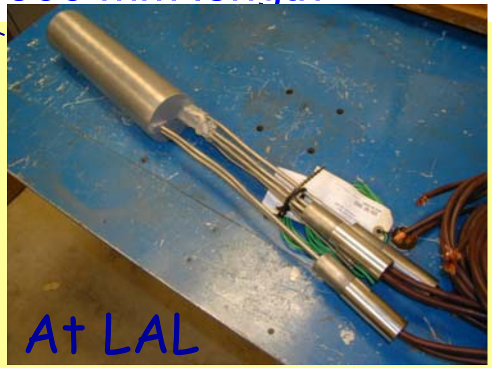
The gain in surface exchange is somewhat lost by the thickness increase and then the heat load increase…

20kW/surface exchange
275kW/m^2

R&D: water cooling is still ok?



Aluminum alloy cylinder
80 mm ext. diameter
300 mm length

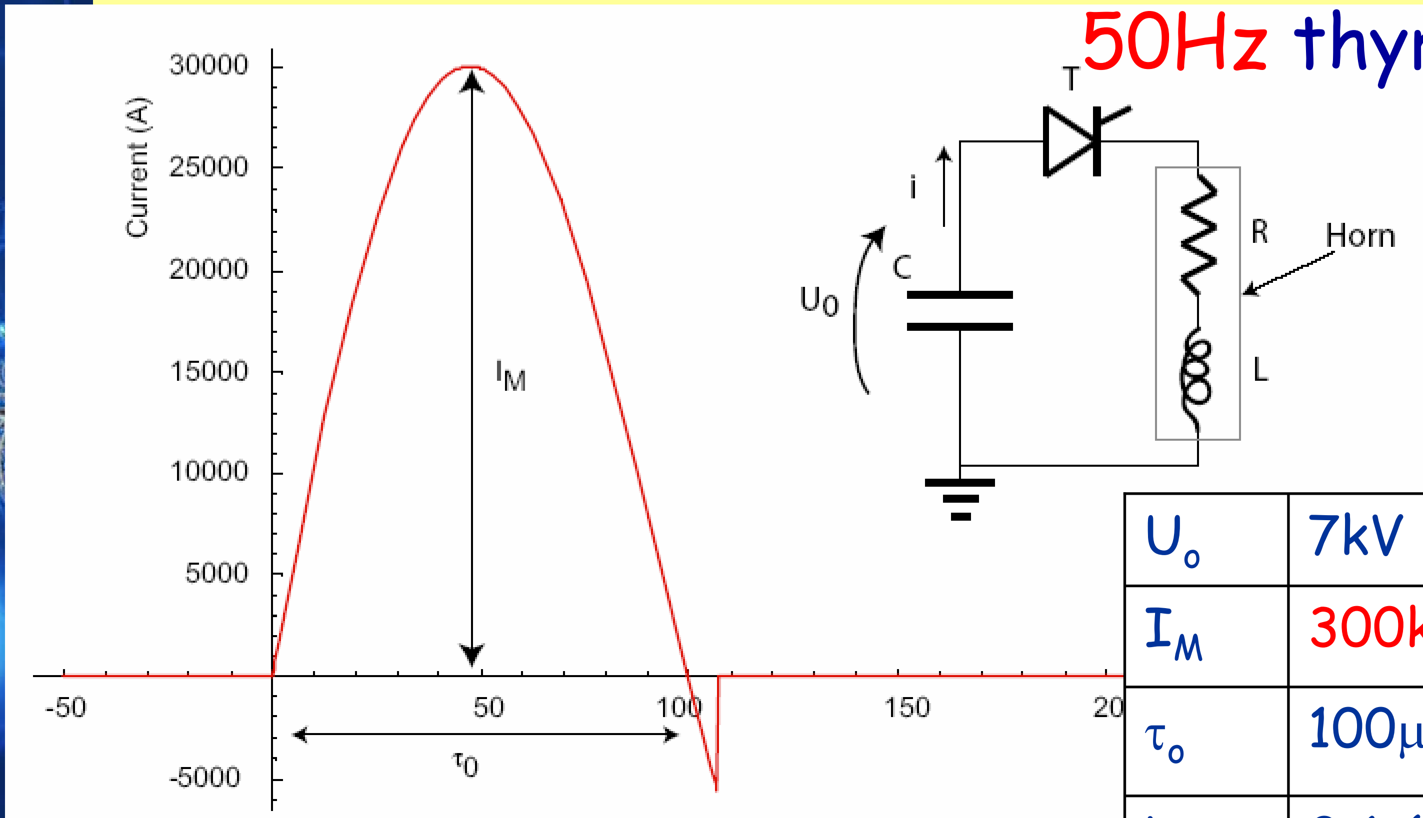


Contact me if you plan to do it

Power Supply (basic)

The main trouble

50Hz thyristors



U_o	7kV
I_M	300kA (14,5 rms)
τ_o	100μs
L	0.6 (0.4 Horn)μH
R	500 (180 Horn) μΩ
C	1500μF

50Hz: 20 x « μ life time »

Power Supply

- CERN had successfully tested the Horn at 100kA/(0.5)Hz
- mid-June 03: a schedule of conditions have been written by LAL (13p) for a (300kA/100μs/50Hz) power supply.

1st industrial price feed back:

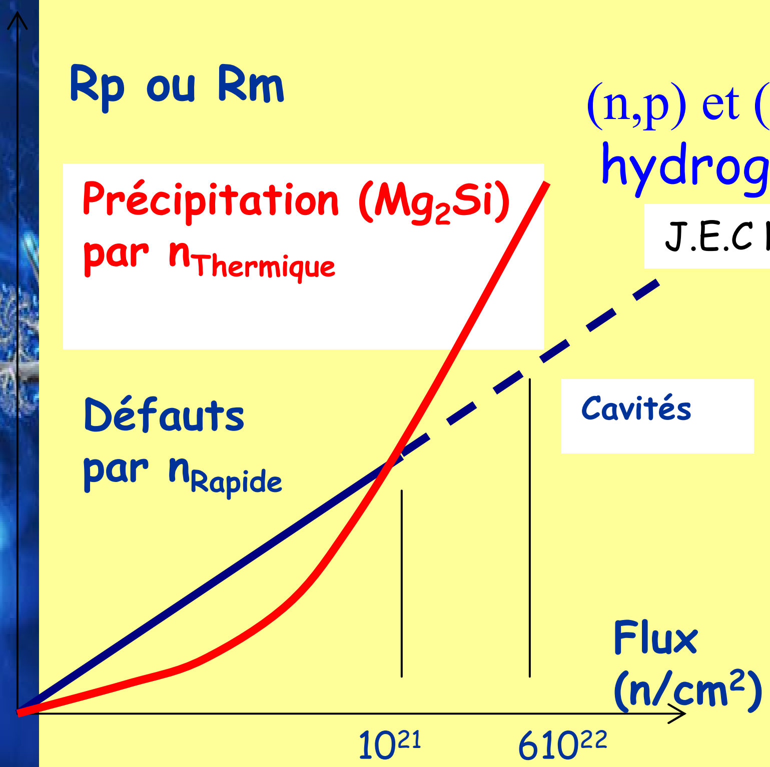
1. Main power supply (7kV/130A): HAZEMEYER co.: ~ 160k€
2. Switches (300kA/100μs/50Hz): ABB co: ~ 3x2x50k€* = 300k€

⇒ **A solution exists for ~ 460k€ (700kCH)**

But we think that a 300kA/1Hz may be a good next step to push the present CERN power supply prototype..

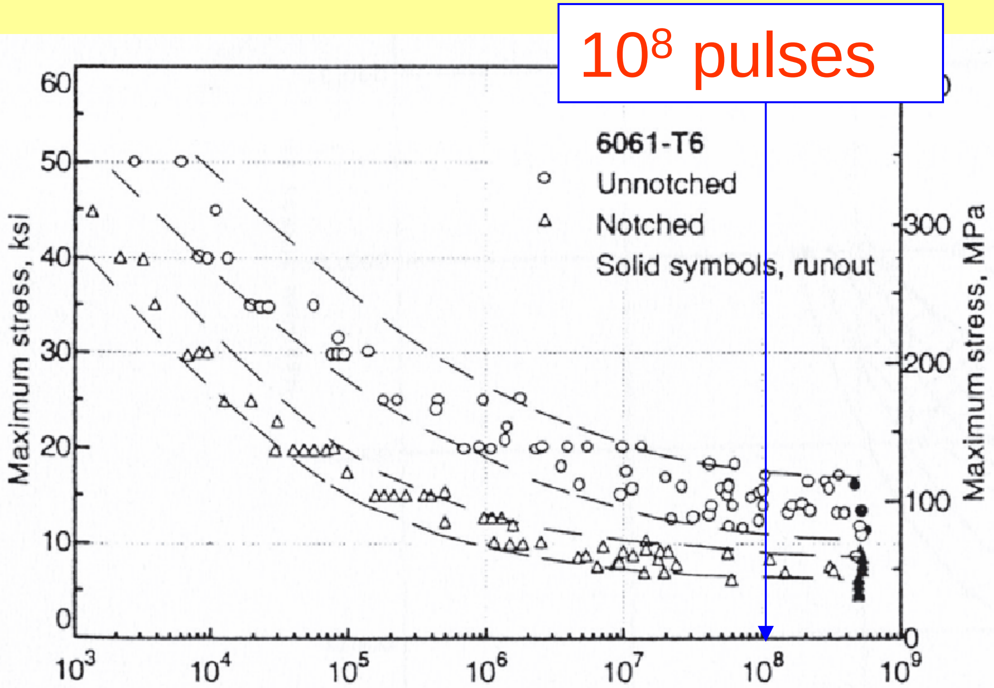
*: factor 2 for # of switches, factor 3 for 1Hz -> 50Hz

Al alloy property modifications



(n,p) et (n,α) reactions produce hydrogen and helium cavities

J.E.C NuFact-Note-130



6082 (CNGS) or 6061 (MiniBOONE)

Non irradiated Al can stand more than 10^8 pulses And also MiniBOONE…

Max. stress ~ 14MPa to be confirmed

Other problems…

- Integration of the Target
- Compatibility with Hg
- Radioactive water cooling treatment
- Water Cooled Striplines
- Fabrication cost issues if the life time of a horn is < 1y
- Fast Coupling (cooling & electric) remotely controlled (see US/Japan example)
- Nuclear waste management

…

Summary

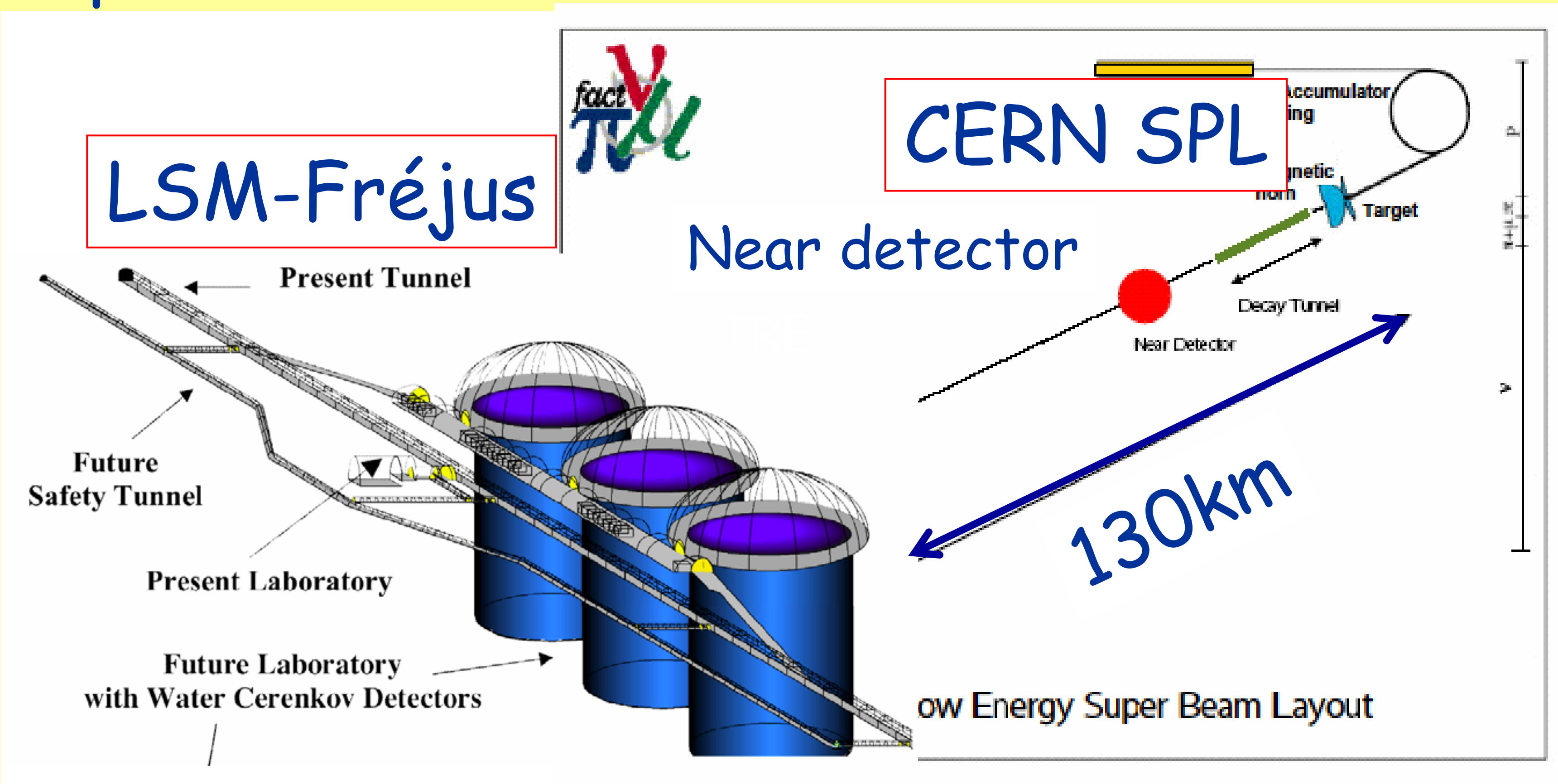
- An optimized version of the Horn-like collection/focusing and SuperBeam energy is available with the present knowledge of the π/K production x-sections and the detector performances.
- The Horn R&D has been interrupted more or less in 2002 at CERN and not revived yet elsewhere.
- The Horn-like collection has been demonstrated in the past to be equivalent to a Solenoid-like collection for a NuFact. The SB-Horn and the NF-Horn are different simply because they have different purposes, but they share a lot of design parameters, so a SB-Horn is a prototype for a NF-Horn.

Thank you

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

END

A possible schema



Related talks

Machines
R. Garoby & M. Lindroos

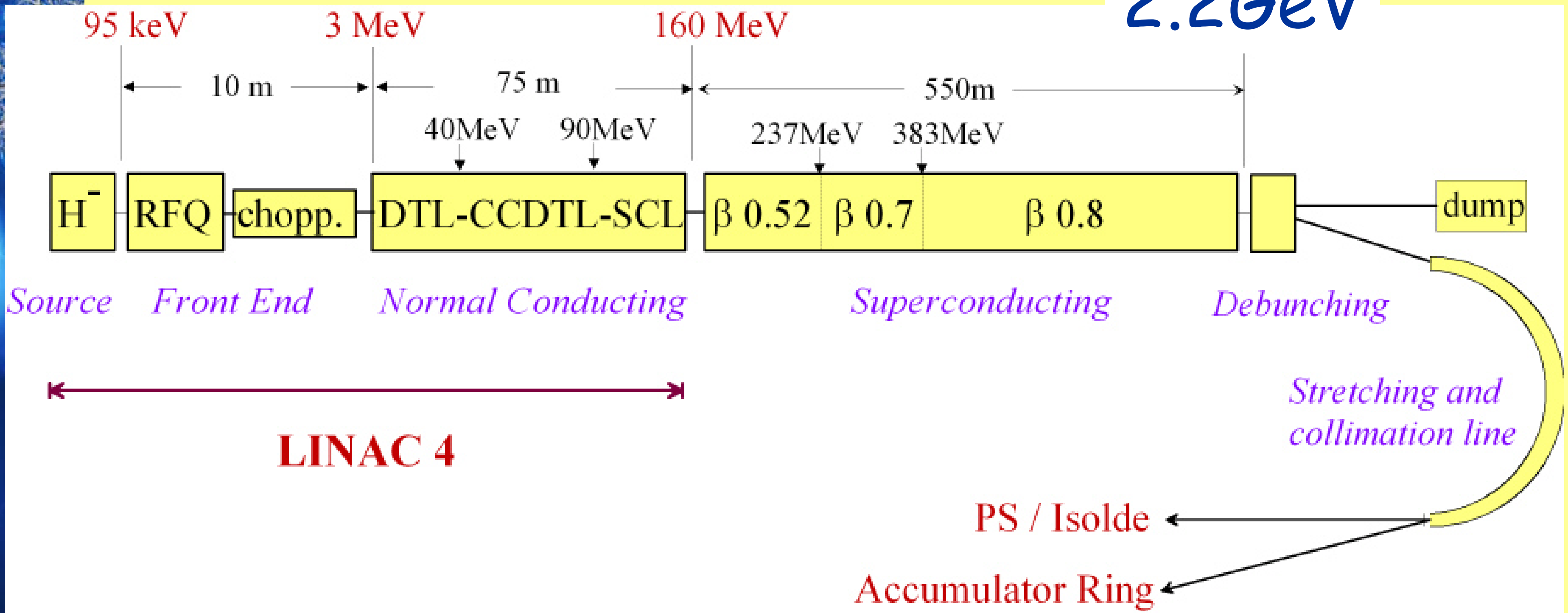
+ BetaBeam: see M. Mezzetto
+ ATM ν: see Th. Schwetz

SPL block diagram (CDR 1)

Characteristics (Conceptual Design Report 1):

- are "optimized" for a neutrino factory
- assume the use of LEP cavities & klystrons up to the highest energy

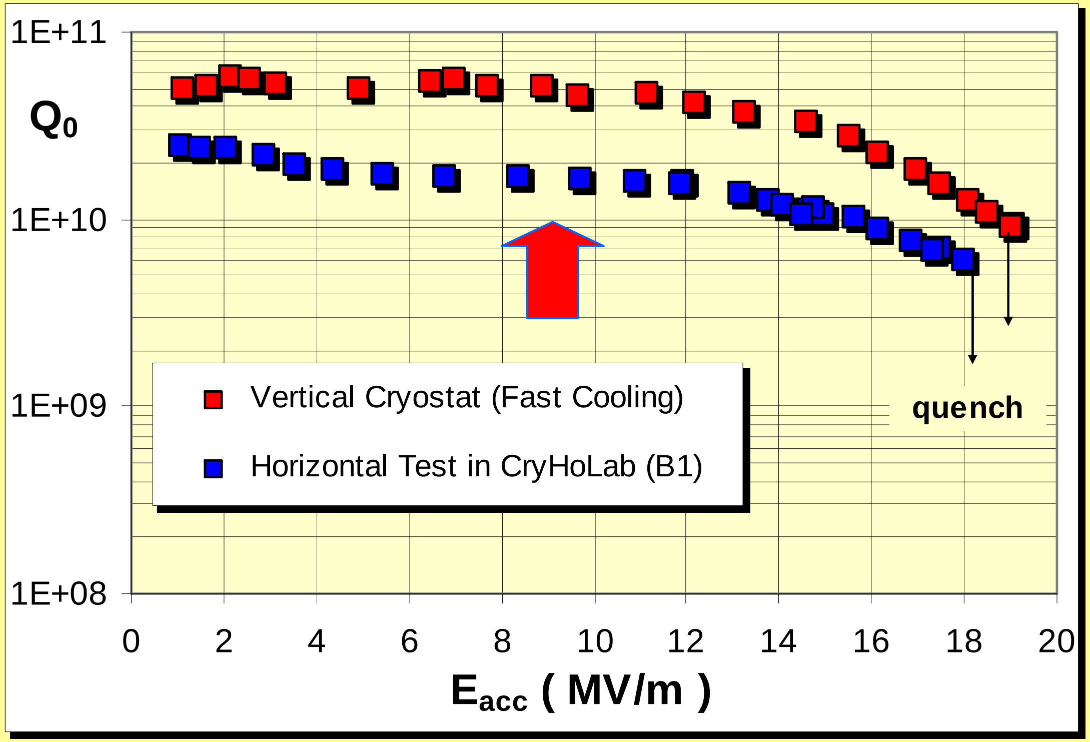
2.2GeV



Gradients at 700 MHz

from Stephane Chel, HIPPI04, Frankfurt, sep04

Last test performed in CryHoLab (July 04):
5-cells 700 MHz ß=0.65 Nb cavity A5-01
from CEA/Saclay and IPN-Orsay



LEP cavities may have worked 350MHz & 3.6MV/m effective gradient
NuFact Note 040

Δm^2_{21}=8 10^{-5}eV^2, Δm^2_{31}=2.4 10^{-3}eV^2, L=130km

$c_{23}=s_{23}=1/\sqrt{2}$, $\tan^2\theta_{12}=0.4$

Choice of the Energy

Neglecting Matter effect (Ok CERN-Frejus), for δ_{CP} = 0°

$$P_{\nu_\mu\to\nu_e} \simeq 4c_{13}^2 s_{13}^2 s_{23}^2 \sin^2\Delta_{31} + (8c_{12}s_{12}c_{13}^2 s_{13}s_{23}c_{23} - 8s_{12}^2 c_{13}^2 s_{13}^2 s_{23}^2)\Delta_{21}\cos\Delta_{13}\sin\Delta_{31}$$

$$\Rightarrow \frac{\alpha}{2}\left[\cos\beta - \cos(2\Delta_{13}+\beta)\right]$$

Maximum of probability is obtained for

$$\Delta_{31} = \frac{\pi}{2} - \frac{\beta}{2} \quad \text{with} \quad \tan\beta = 2\Delta_{21}\frac{c_{12}s_{12}c_{23}}{s_{13}s_{23}}$$

2famillies formula ($\Delta_{31} = \frac{\pi}{2}$)

E_ν = 250MeV

$\sin^2 2\theta_{13}=10^{-2}$, E_ν =320MeV

$\sin^2 2\theta_{13}=10^{-3}$, E_ν =390MeV

Decay Tunnel Parameters

Length

1. modify purity
2. L=10m, 20m, 40m and 60m have been tested.
3. 10m→40m
   - $\bar{\nu}_\mu$, ν_μ + 50% to 70%
   - $\bar{\nu}_e$, ν_e + 50% to 100%
4. 40m→60m
   - $\bar{\nu}_\mu$, ν_μ + 5%
   - $\bar{\nu}_e$, ν_e + 20%

40m seems better

Radius

1. modify acceptance
2. R=1m, 1.5m and 2m have been Tested
3. 1m →2m (L=40)
   - $\bar{\nu}_\mu$, ν_μ +50%
   - $\bar{\nu}_e$, ν_e +50% to 70%

Larger is better (2m)…

This results have been checked on sensitivity to θ_{13} and δ_{CP}