SPL→Fréjus

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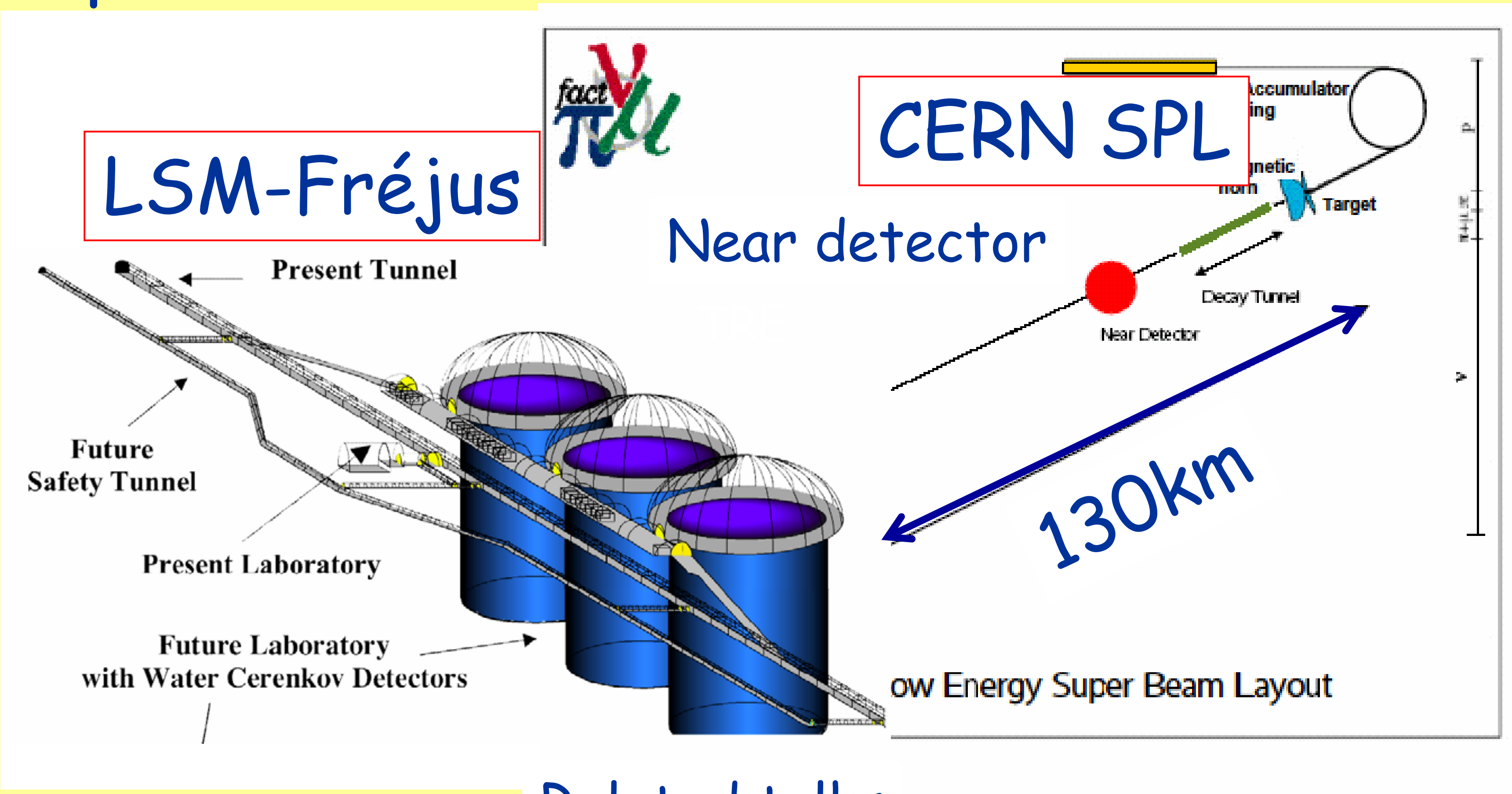
Thanks: A. Cazes, M. Mezzetto, Th. Schwetz
and the GLoBES team
and AM Lombardi, R. Garoby

A possible schema



Related talks

Machines
R. Garoby & M. Lindroos

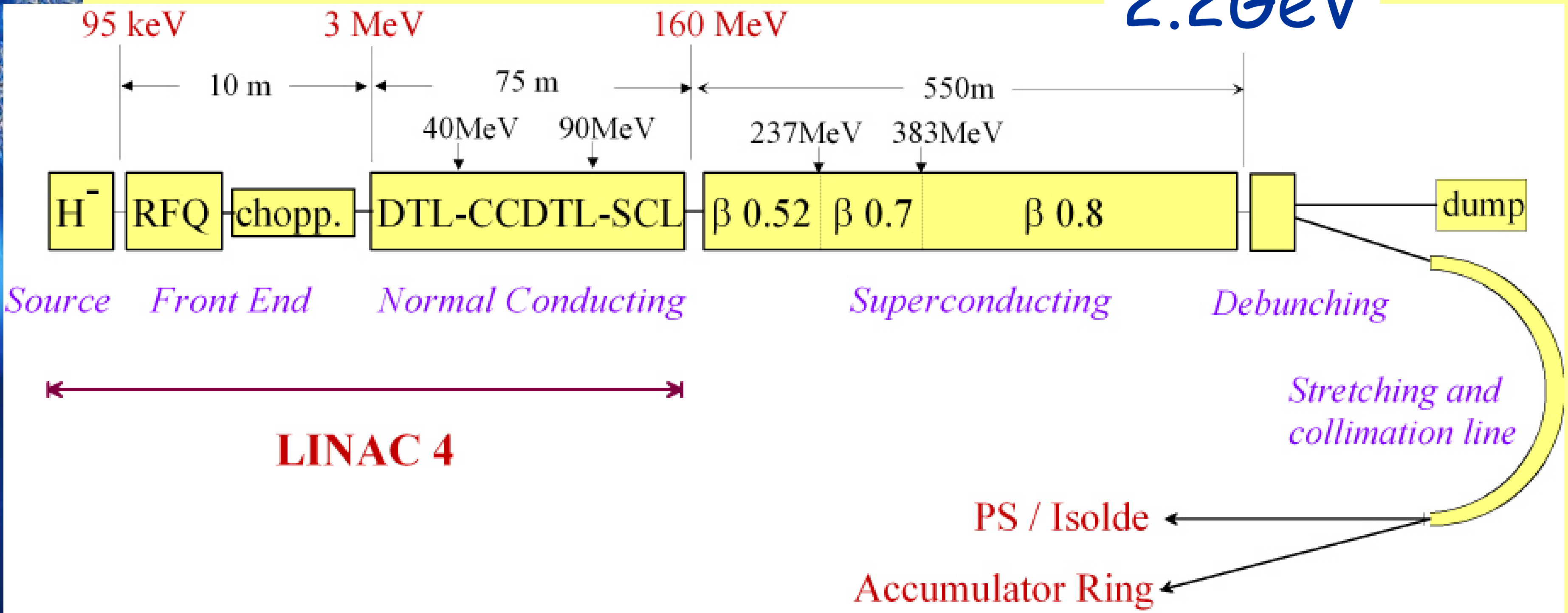
+ BetaBeam: see M. Mezzetto
+ ATM ν: see Th. Schwetz

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

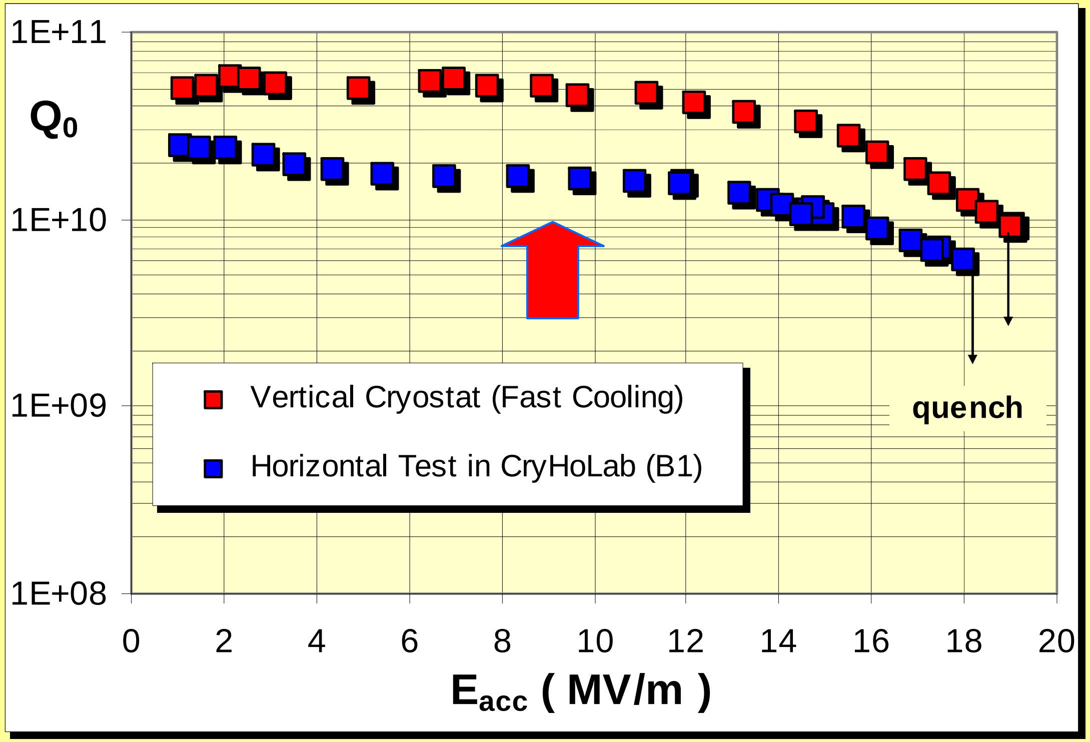
2.2GeV



Gradients at 700 MHz

from Stephane Chel, HIPPI04, Frankfurt, sep04

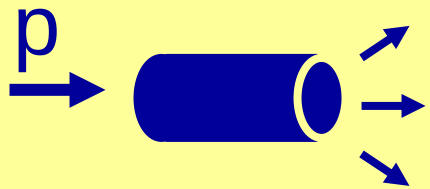
Last test performed in CryHoLab (July 04):
5-cells 700 MHz ß=0.65 Nb cavity A5-01
from CEA/Saclay and IPN-Orsay



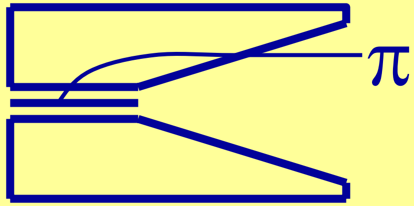
LEP cavities may have worked 350MHz & 3.6MV/m effective gradient
NuFact Note 040

New optimization questioned @ MMW04*

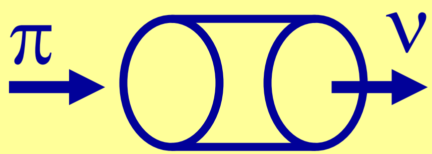
Particle production



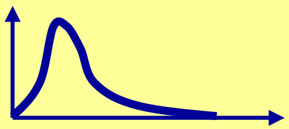
Horn design optimisation



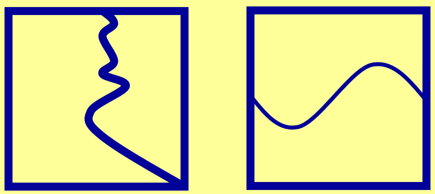
Decay tunnel parameter
optimisation



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**…

Target :

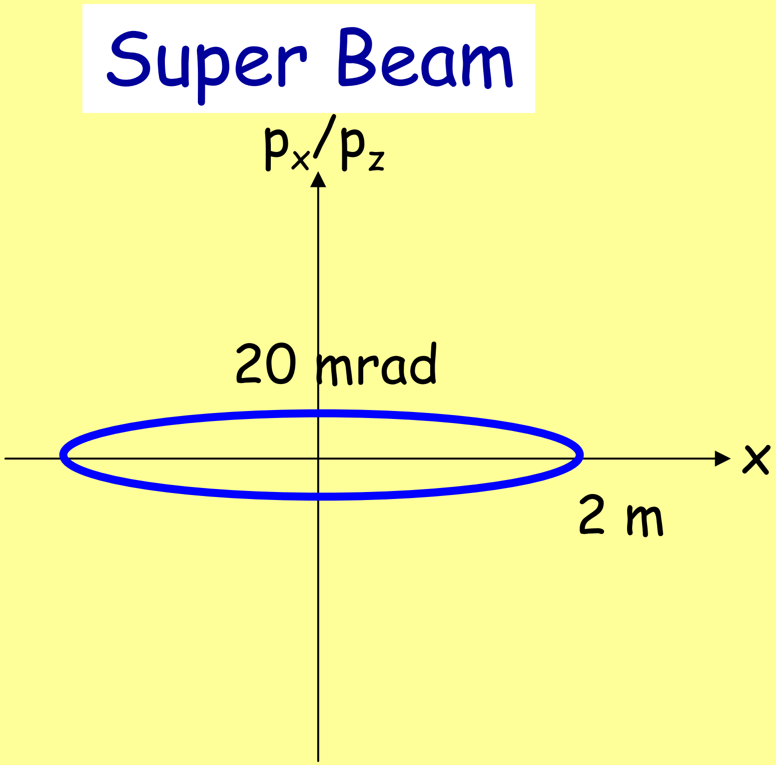
1. 30cm long cylinder, ∅15mm in Liq. Hg
2. FLUKA 2002.4

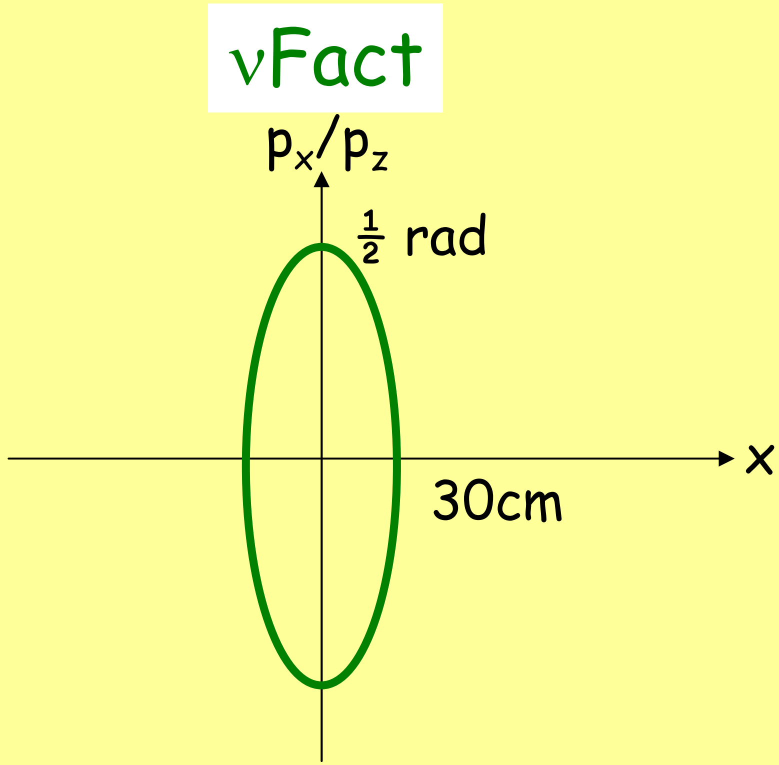
Normalized to a power of 4MW:

$1.14\ 10^{23}$ pot/yr @ 2.2GeV

$0.71\ 10^{23}$ pot/yr @ 3.5GeV

SuperBeam vs νFact Optics



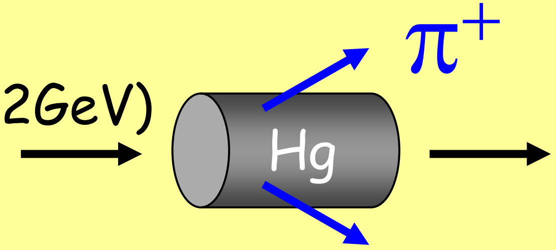


Spot size @ 130km
Decay tunnel size

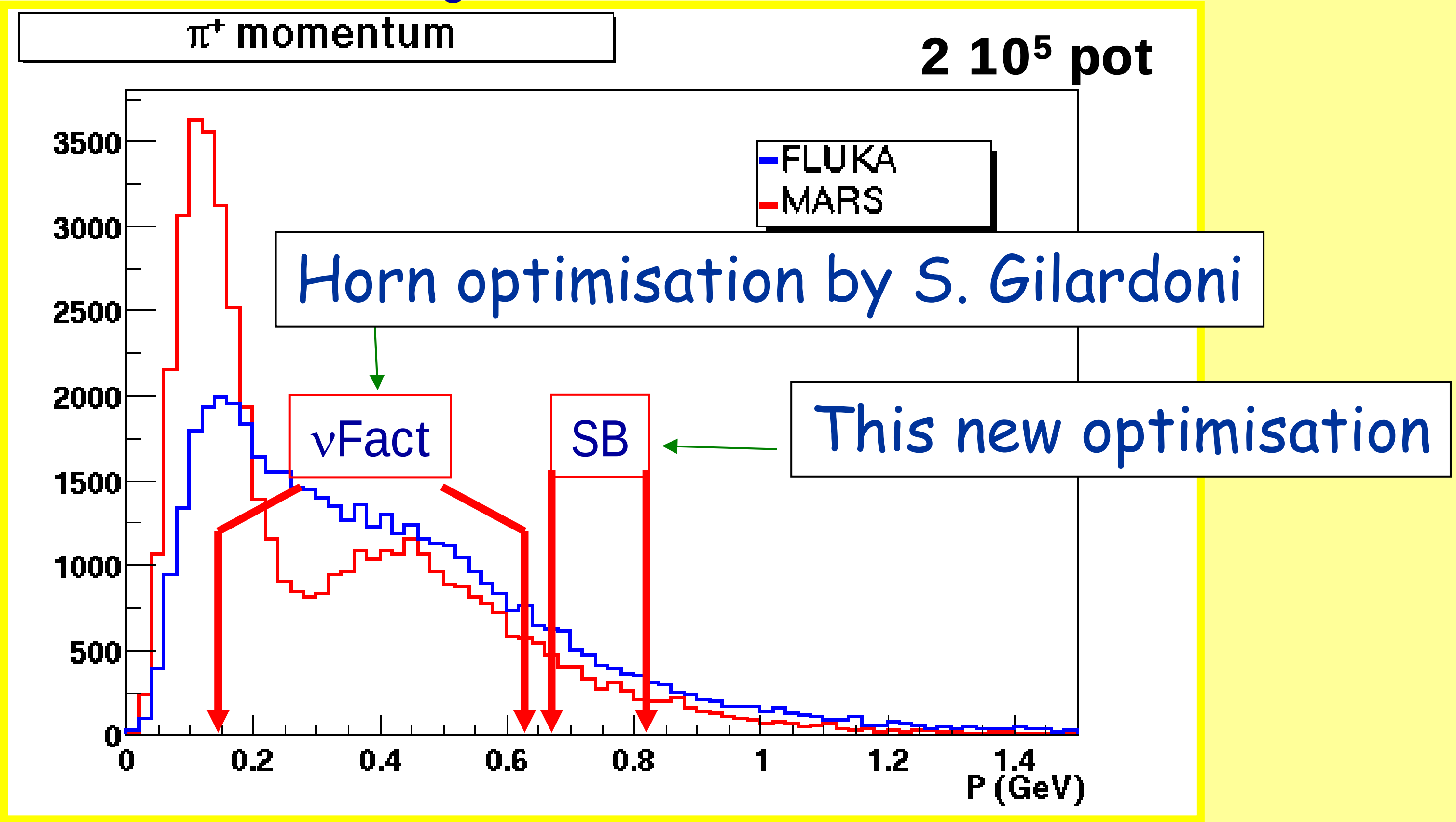
Decay channel solenoids
Aperture and B strength

Thanks S. Gilardoni

Pion production



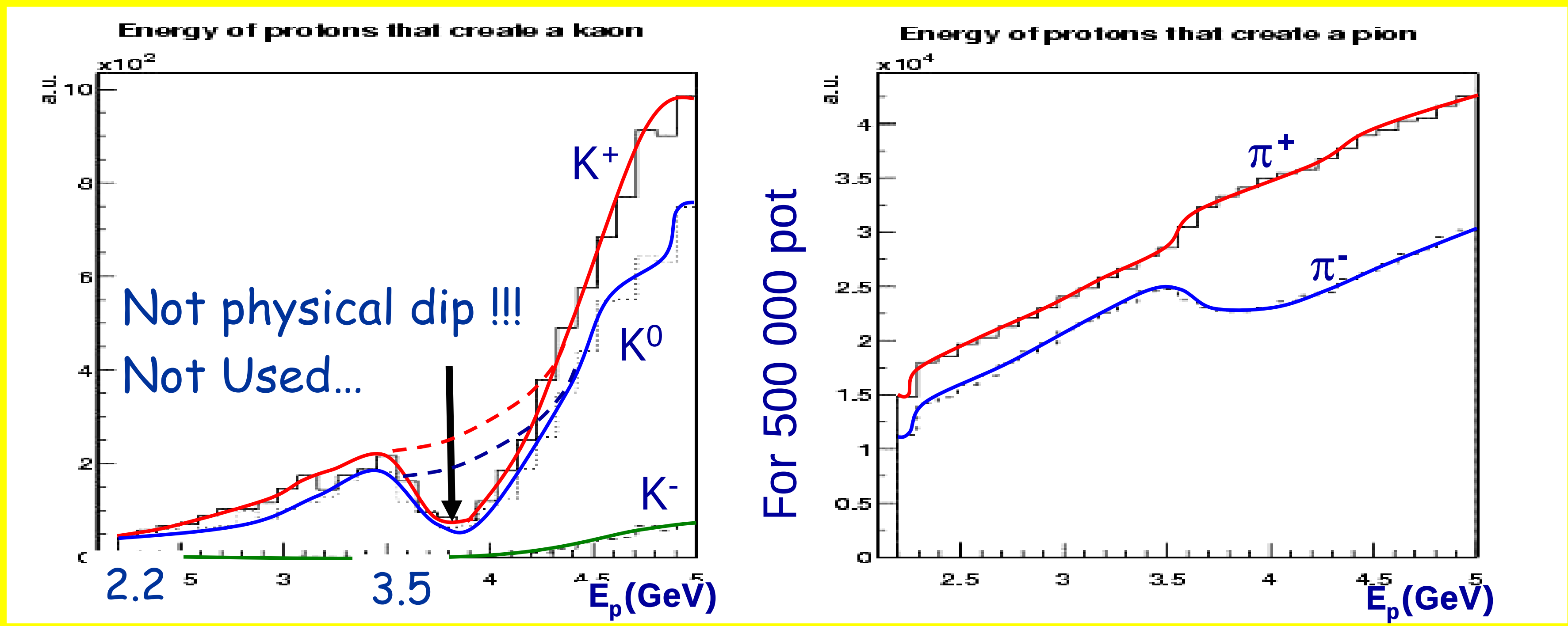
at the exit of the target



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

Kaon production?

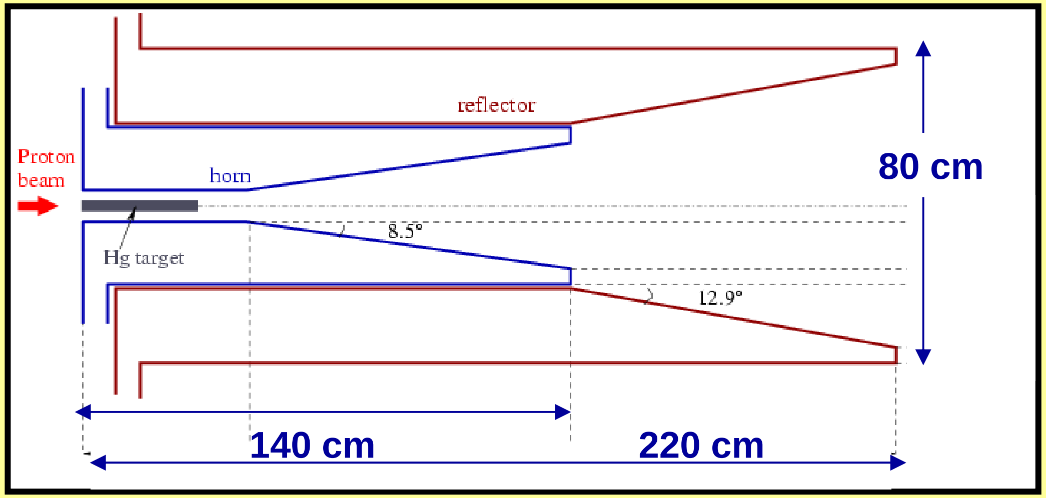
see BENE meeting 11/09/03



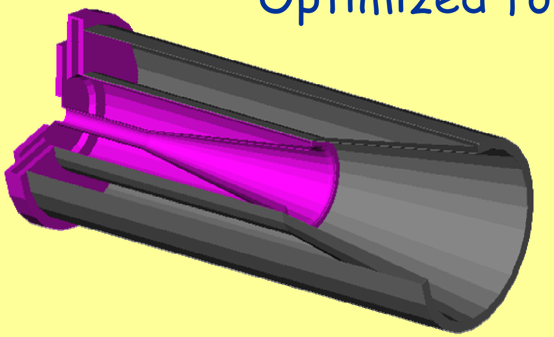
- at 2.2GeV :
  - 0.26 π^+/s
  - 0.8 10^{-3} K^+/s
- at 3.5GeV :
  - 0.29 π^+/s
  - 2.8 10^{-3} K^+/s
- at 4.5GeV :
  - 0.32 π^+/s
  - 5.2 10^{-3} K^+/s

Horn design parameter

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

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

Using Geant 3.2.1
NuFact-Note 138

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

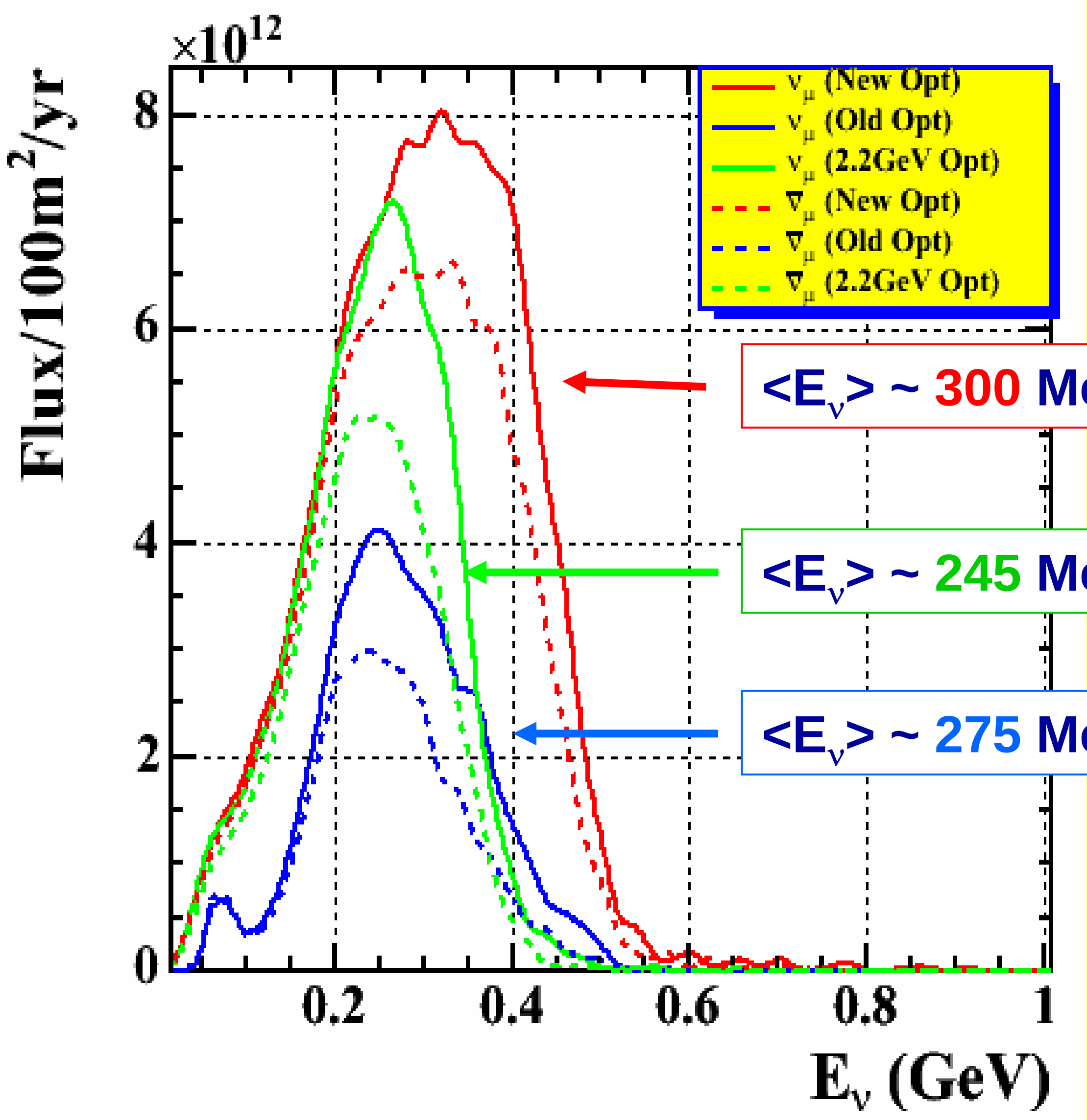
Radius

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}

Fluxes comparison @ 130km



~95 ν_μ^{CC}/kT/yr*

$<E_\nu>$ ~ 300 MeV, 1.2 10^{14}/100m^2/yr

3.5GeV SPL optimum

$<E_\nu>$ ~ 245 MeV, 7.5 10^{13}/100m^2/yr

2.2GeV SPL optimum

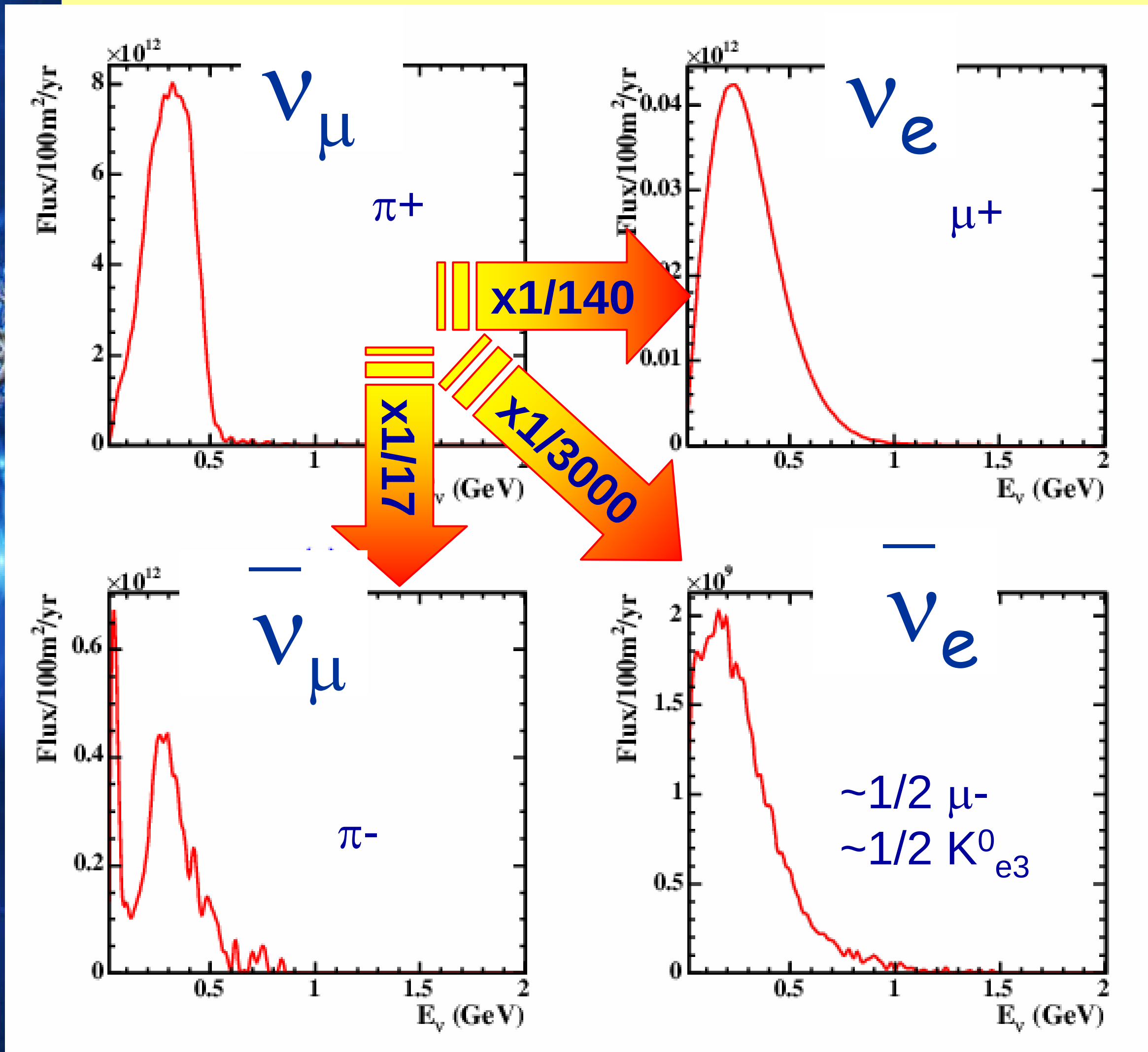
$<E_\nu>$ ~ 275 MeV, 4.5 10^{13}/100m^2/yr

Old νFact optimum

*: Lipari x-sect. (see later)

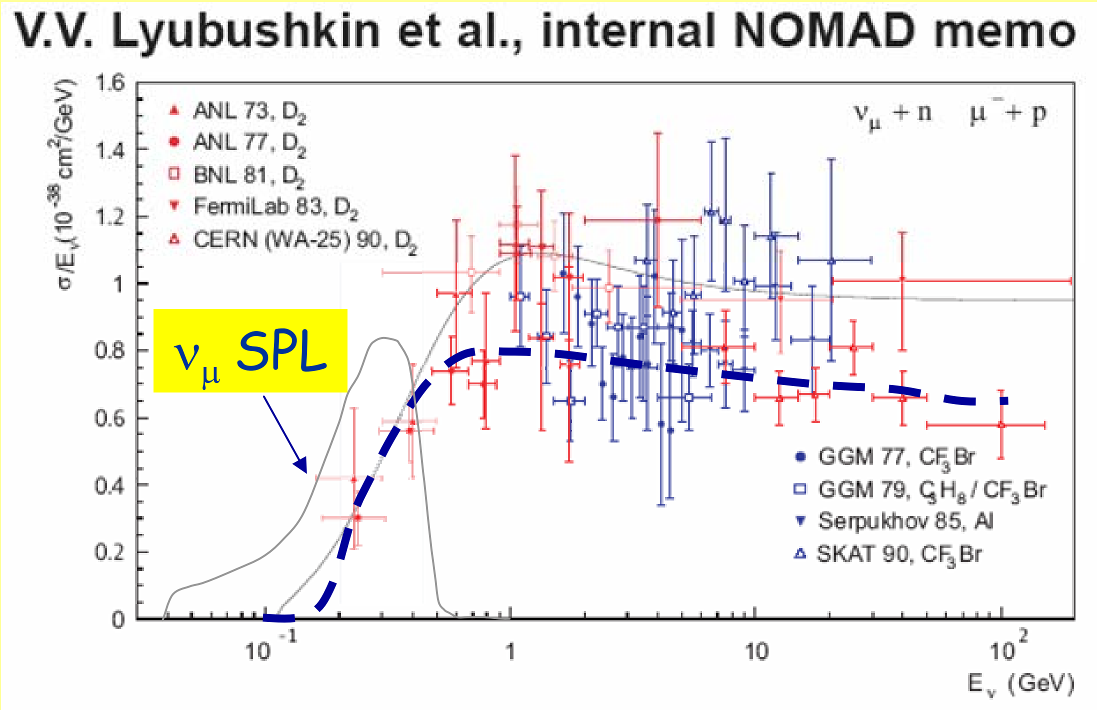
Flux @ 130km: + focusing

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. 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.

Analysis: GLoBES + M. Mezzetto's parameterization file

440kT x 5yrs: 2,2 Mt.yrs (+)

	$\theta_{13} = 1°$	$\theta_{13} = 3°$	$\sin^2 2\theta_{13} = 0.05$	
$\nu_\mu \to \nu_e$ (Sig)	**33** ($\delta = \pi/2$)	**330** ($\delta = \pi/2$)	**2200** ($\delta = \pi/2$)	**3670** ($\delta = 0°$)
$\nu_\mu \to \nu_e$ (Bkg)	**1500**			
	$\nu_e \to \nu_e$ CC	π^0 from NC	$\nu_\mu \to \nu_\mu$ CC (μ missId)	$\bar{\nu}_e \to \bar{\nu}_e$ CC
Frac. of Bkg	90%	6%	3%	1%
Reduction Factor	0.707(1060)	$6.5\ 10^{-4}$(90)	$5.4\ 10^{-4}$(45)	0.677(15)
$\nu_\mu \to \nu_\mu$ (Sig)	**64950** ($\delta = \pi/2$)		**64414** ($\delta = 0°$)	
$\nu_\mu \to \nu_\mu$ (Bkg)	**3** ($4.3 10^{-5}$ $\bar{\nu}_\mu \to \bar{\nu}_\mu$ CC)			

$\sin^2 2\theta_{12}=0.82$, $\theta_{23}=\pi/4$, $\Delta m^2_{21}=8.1\ 10^{-5} eV^2$, $\Delta m^2_{31}=2.2\ 10^{-3} eV^2$

Reduction factor and efficiencies taken from SK simulation (D. Casper) and a tight cut for e/μ misId. (cf. hep-ph/0105297)

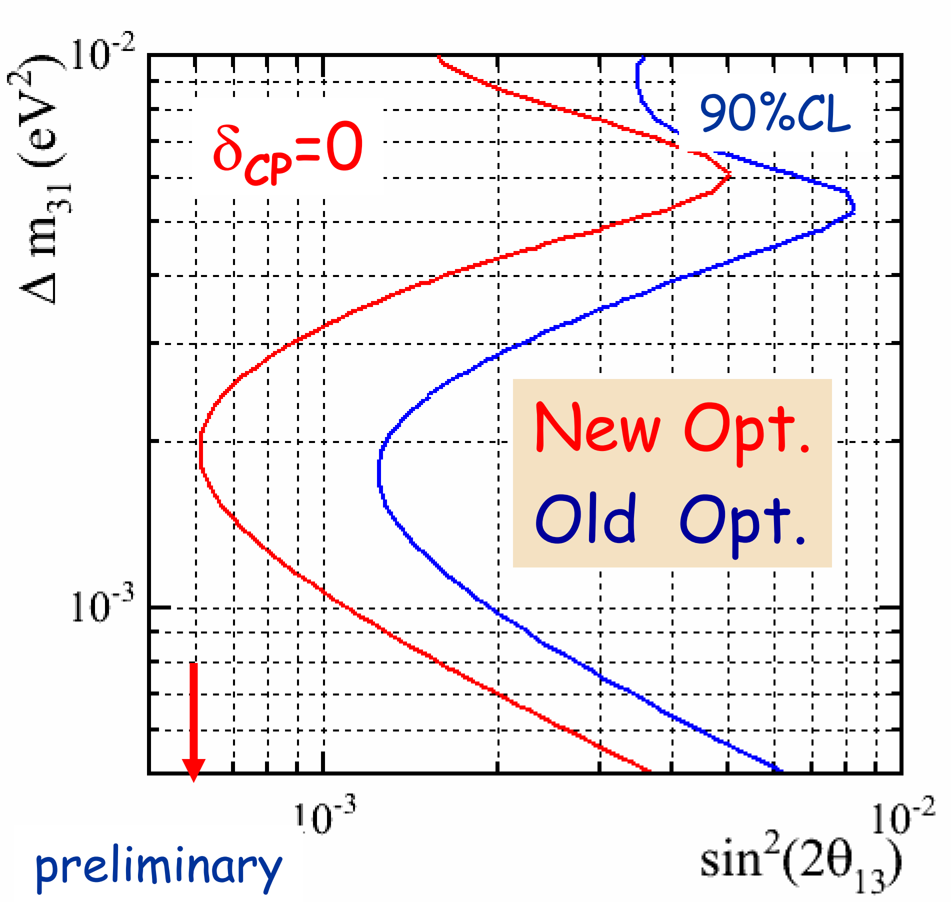
440kT x 8yrs: 3,5 Mt.yrs (-)

$\bar{\nu}_\mu \to \bar{\nu}_e$ (Sig)	$\theta_{13} = 1°$ $\sin^2 2\theta_{13}$= 0.001	$\theta_{13} = 3°$ $\sin^2 2\theta_{13}$= 0.01	$\sin^2 2\theta_{13}$= 0.05	
	110 ($\delta = \pi/2$)	**390** ($\delta = \pi/2$)	**1300** ($\delta = \pi/2$)	**1140** ($\delta = 0°$)
$\bar{\nu}_\mu \to \bar{\nu}_e$ (Bkg)	**490**			
	$\bar{\nu}_e \to \bar{\nu}_e$ *CC*	$\nu_e \to \nu_e$ *CC*	π^0 **from NC**	$\bar{\nu}_\mu \to \bar{\nu}_\mu$ *CC* **(μ missId)**
Frac. of Bkg	45%	35%	18%	2%
Reduction Factor	0.677(220)	0.707(170)	$2.5\ 10^{-3}$(90)	$5.4\ 10^{-4}$(10)
$\bar{\nu}_\mu \to \bar{\nu}_\mu$ (Sig)	19760 ($\delta = \pi/2$)		**19590** ($\delta = 0°$)	
$\bar{\nu}_\mu \to \bar{\nu}_\mu$ (Bkg)	**1** ($4.3 10^{-5}$ $\bar{\nu}_\mu \to \bar{\nu}_\mu$ *CC*)			

$\sin^2 2\theta_{12}$=0.82, $\theta_{23}=\pi/4$, Δm^2_{21}=8.1 10^{-5}eV^2, Δm^2_{31}=2.2 10^{-3}eV^2

Some physics performances

440kT water Č, 4MW SPL, opti. Fluxes



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

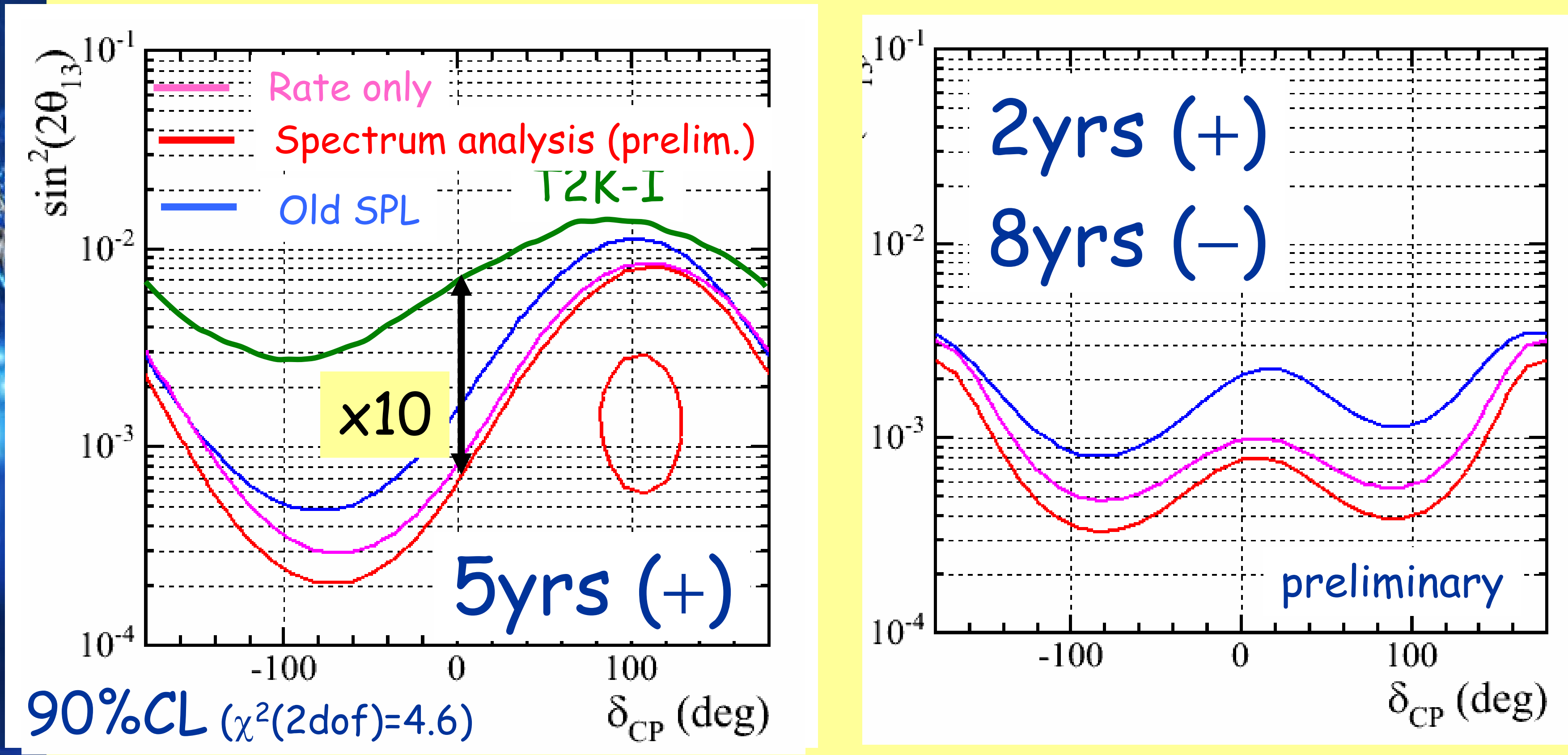
*: 5 bins [0.08,1.08] GeV

(χ^2(2dof)=4.6 or 11.83)

Some physics performances

True values: $\delta_{CP}=0$, $\theta_{13}=0$, $\sin^2 2\theta_{12}=0.82$, $\theta_{23}=\pi/4$, $\Delta m^2_{21}=8.1\ 10^{-5}$, $\Delta m^2_{31}=2.2\ 10^{-3}$

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

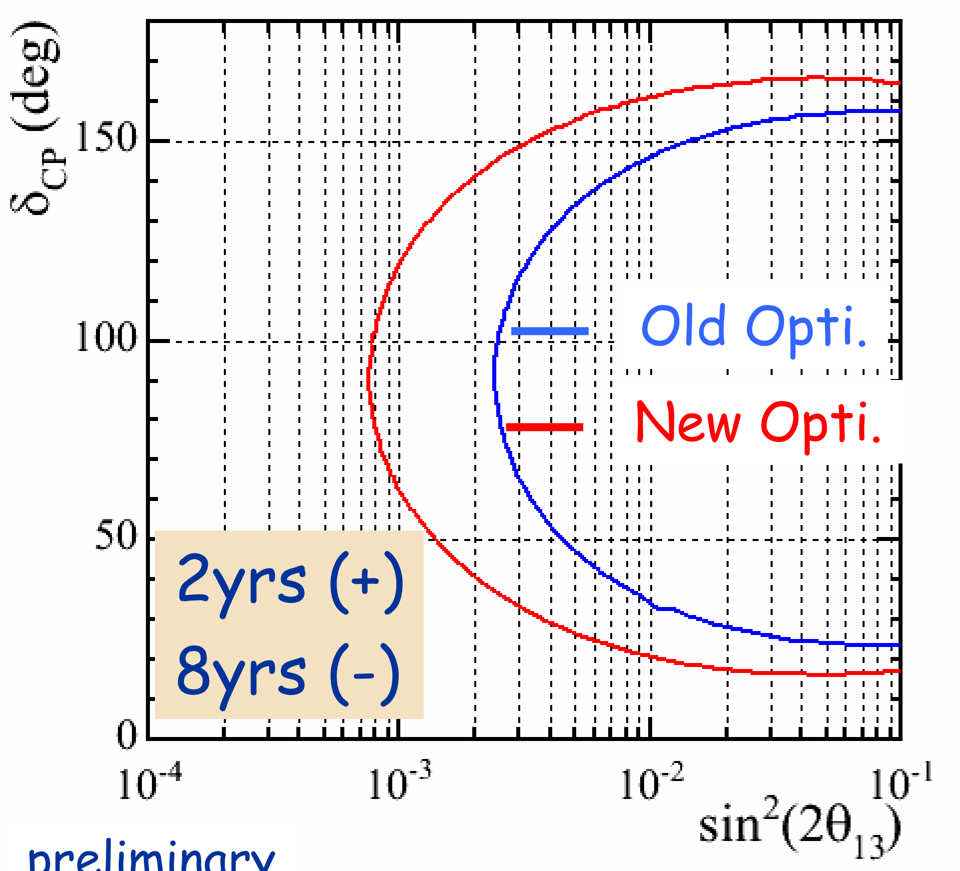


2% syst. on signal & bkg

Improve T2K-I

Some physics performances

CP discovery @ 3σ



preliminary

True values (δ_{CP}, θ)

Tests δ_{CP}=0 and $\delta_{CP}=\pi$

$\sin^2 2\theta_{12}$=0.82, $\theta_{23}=\pi/4$,

$\Delta m^2_{21}=8.1\ 10^{-5}$, $\Delta m^2_{31}=2.2\ 10^{-3}$

5% external precision on θ_{12} and Δm^2_{21}

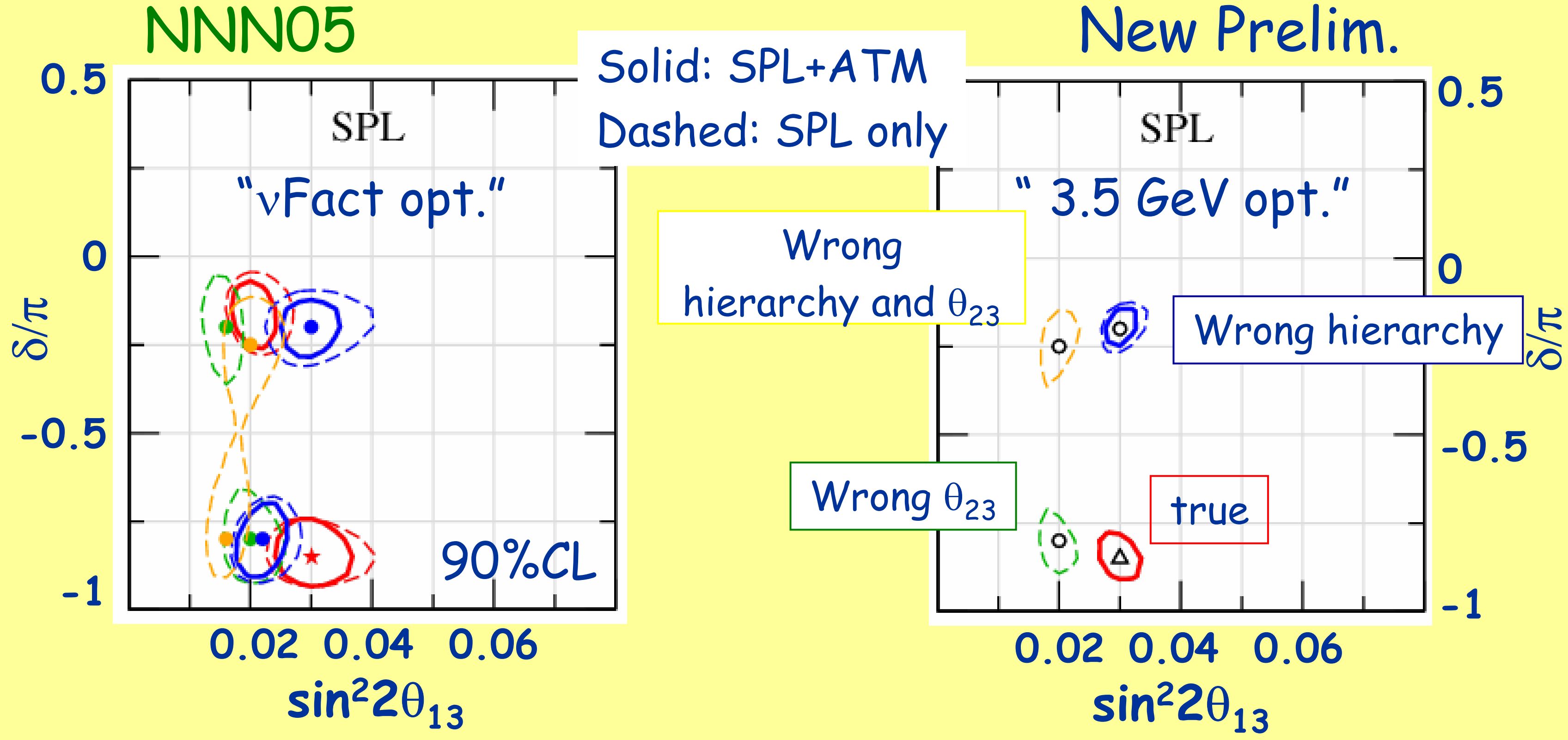
use SPL disappearance channel

2% syst on signal & bkg

Use glbChiDelta and χ^2 (1dof)=9

Evolution of the performances

2yrs (+), 8 yrs (–)

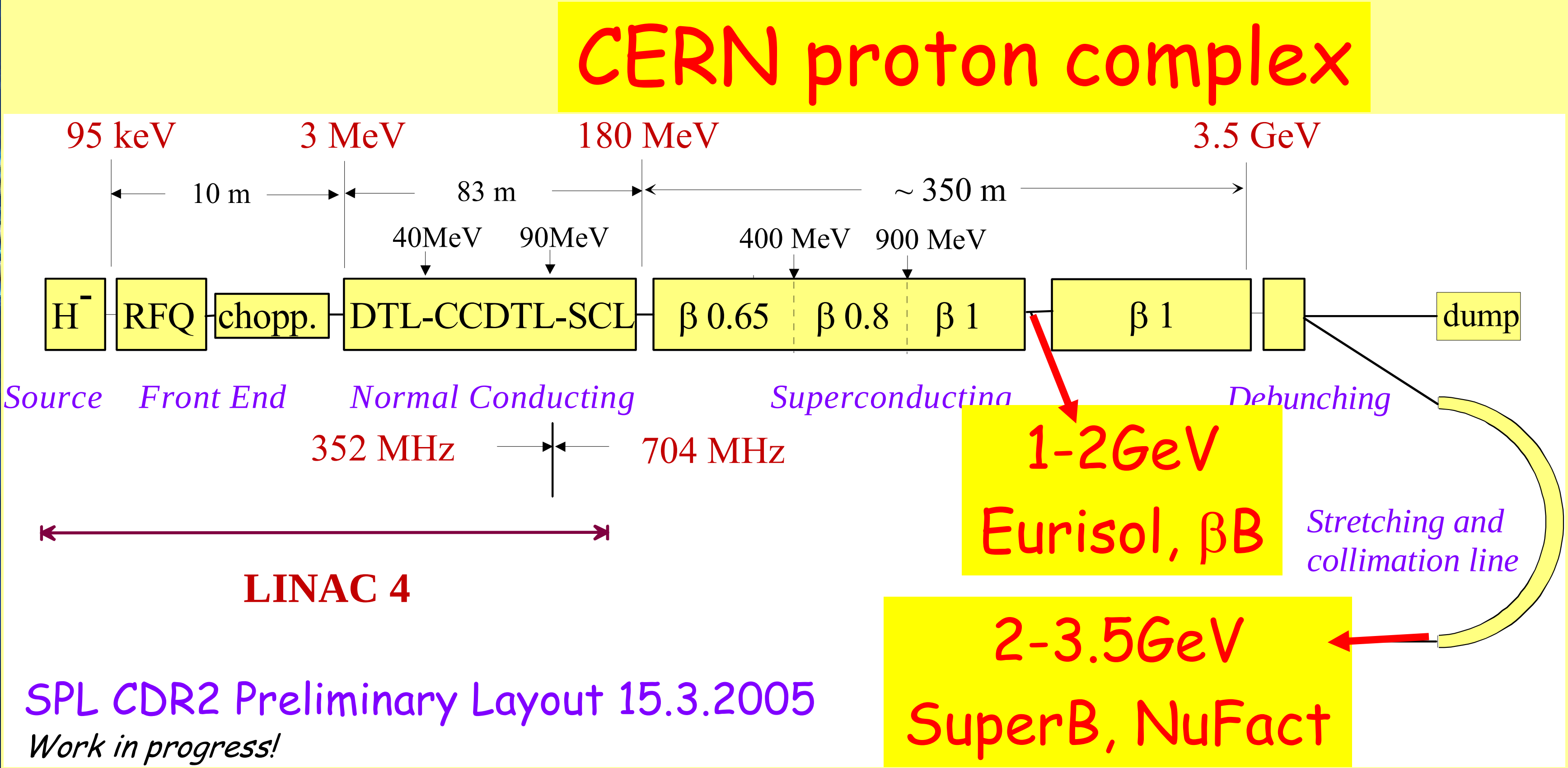


True values: δ_{CP}/π =-0.85, $\sin^2 2\theta_{13}$=0.03, $\sin^2\theta_{23}$=0.4,

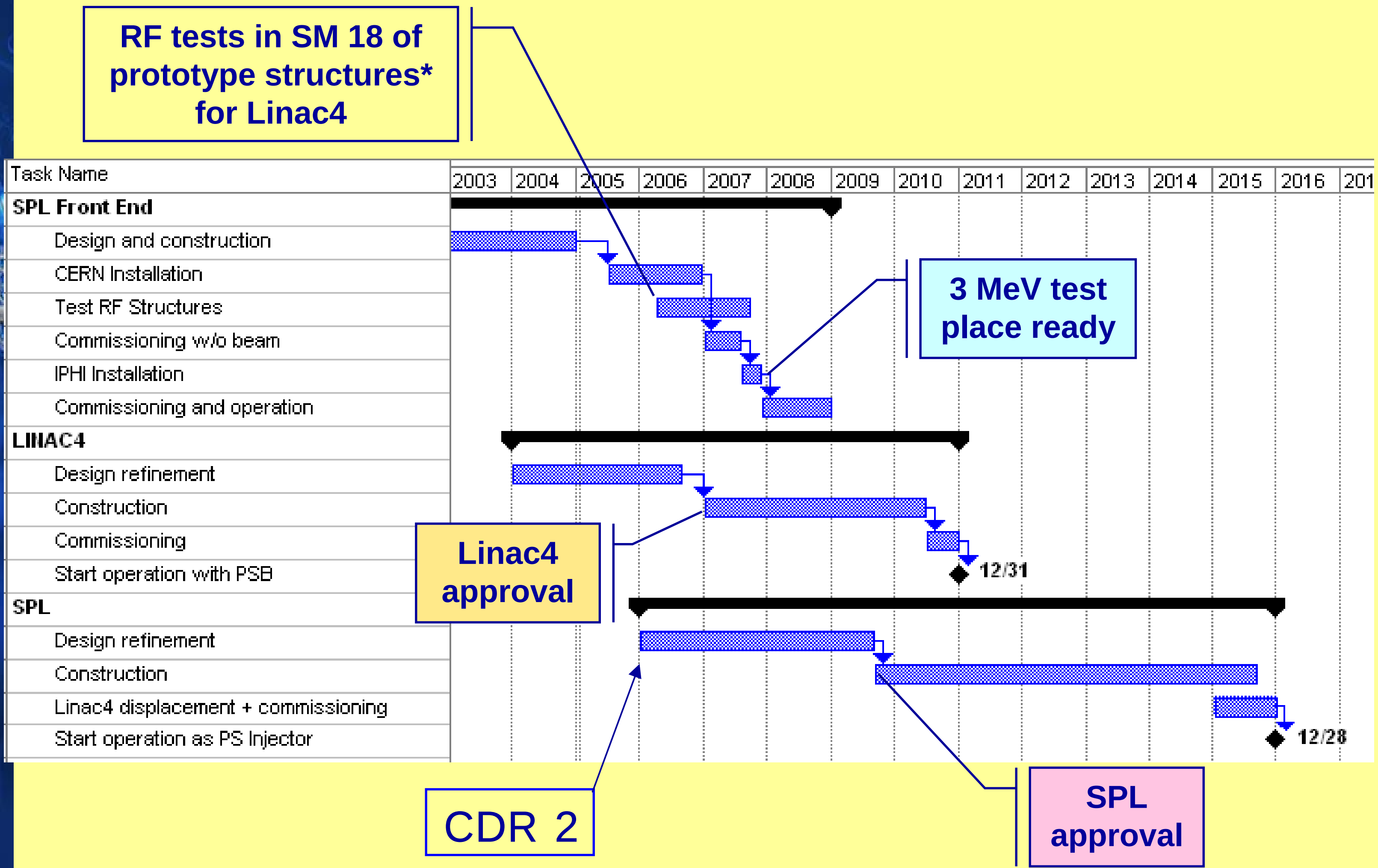
5% external precison on Δm^2_{21}=8.1 10^{-5}, Δm^2_{31}=2.2 10^{-3}, θ_{23}

cf. Th. Schwetz

CDR2 block diagrams



Global planning (R.G courtesy)



Summary

Higher proton energy & SB Horn specific

1. new baseline: 3.5GeV/2m/40m

θ_{13} sensitivity:

- ✓ sensitivity to θ_{13} = 0.7° (5yrs +): gain +25% wrt old result
- ✓ down to θ_{13} = 1.4° with the 10yrs mixed scenario independently of δ_{CP}
- ✓ Improve T2K-I by a factor 10 at δ_{CP} = 0 (5yrs +)

Can discover CP violation

Can solve ambiguities alone and result is improved thanks to ATMν (Th. Schwetz 's talk)

Complementary to BetaBeam to cross check the background and improve δ_{CP} sensitivity (M. Mezzetto's talk)

Thank you