SPL-Fréjus optimisation.

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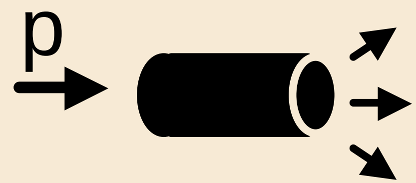
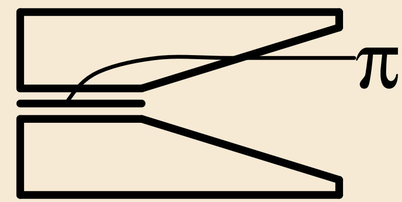
outline

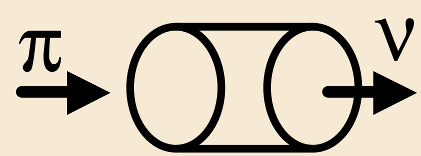
- Particle production



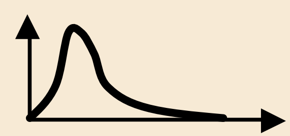
- horn design optimisation
  - Design
  - tracking



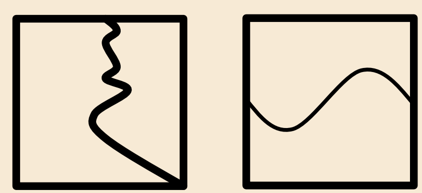
- Decay tunnel parameter optimisation



- Flux computation at Fréjus



- θ_{13} and δ_{CP} sensitivity



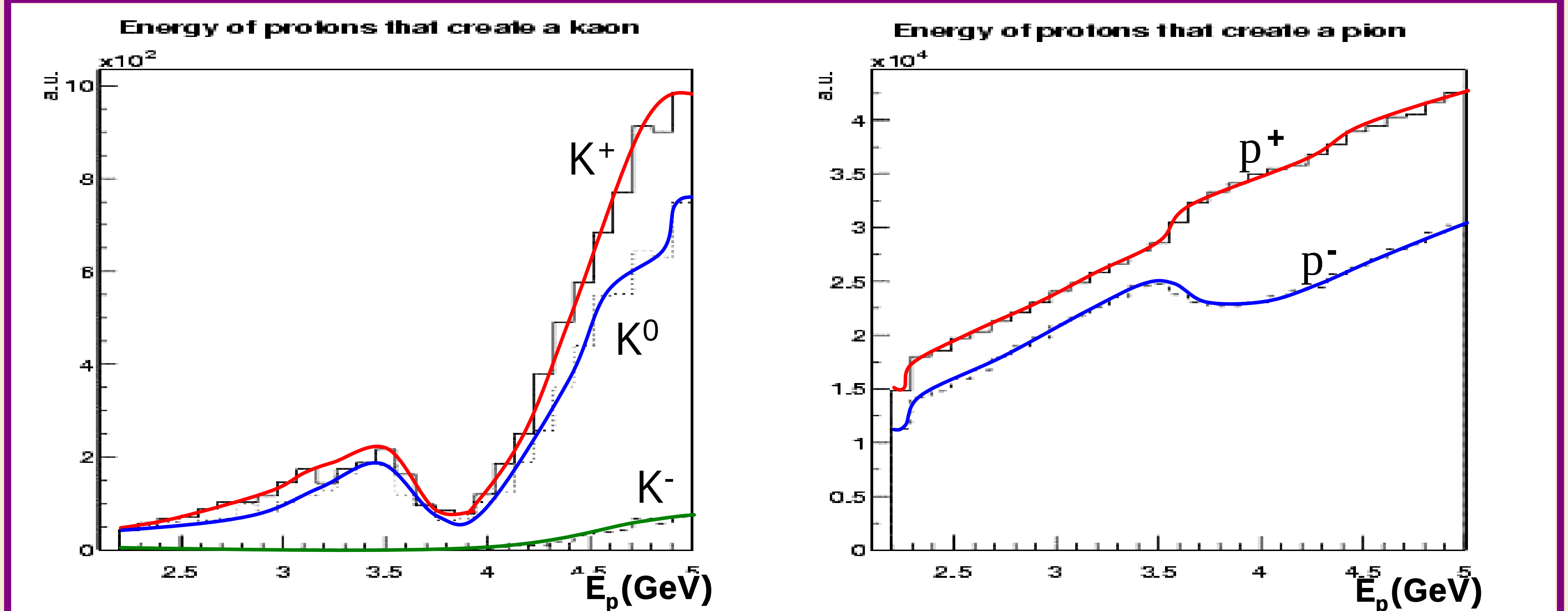
- comparison and conclusion.

Particle production

- Proton beam :
  - Pencil like
  - E_k=2.2GeV, 3.5GeV, 4.5GeV, 6.5GeV and 8GeV
  - 10^6 protons on target
- Target :
  - 30cm long cylinder, ∅15mm in Liquid mercury.
  - FLUKA 2002.4
- Normalized to a power of 4MW.

Kaon production

see BENE meeting 11/09/03



- 500 000 protons, $E_k < 5$GeV
- 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

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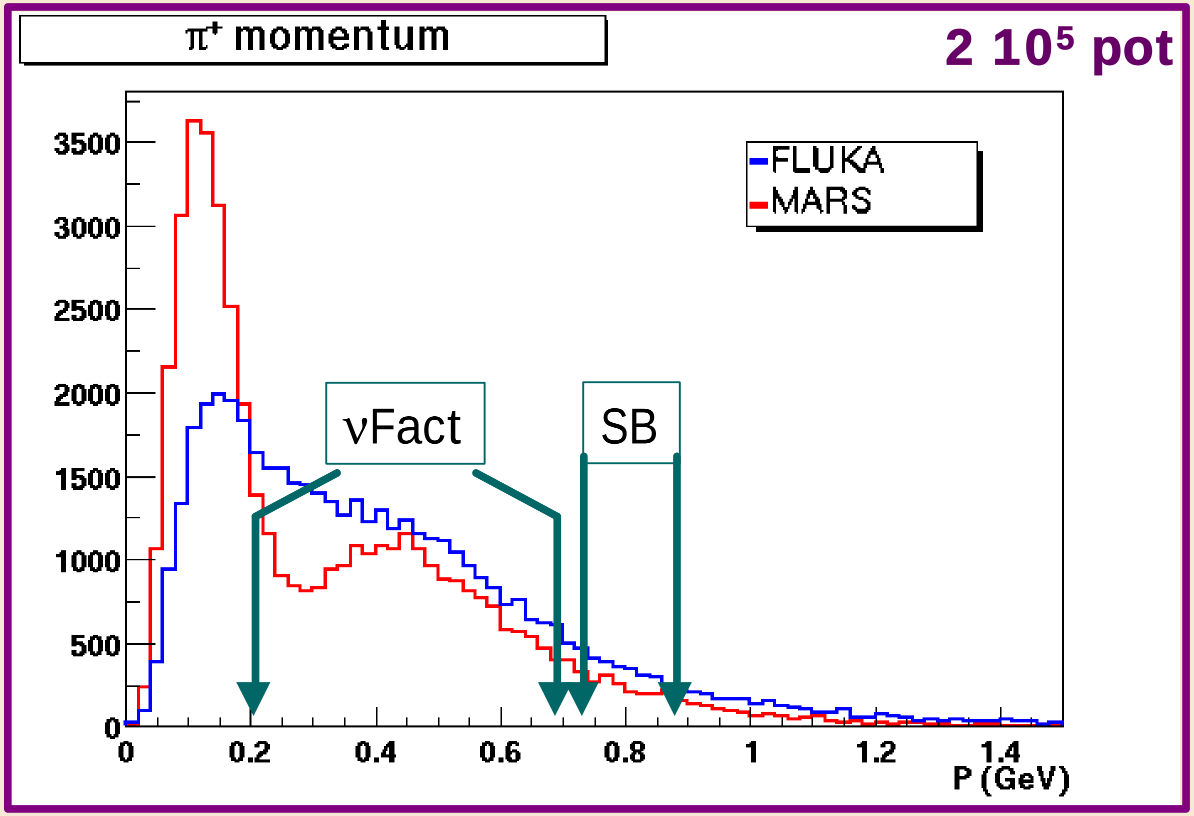
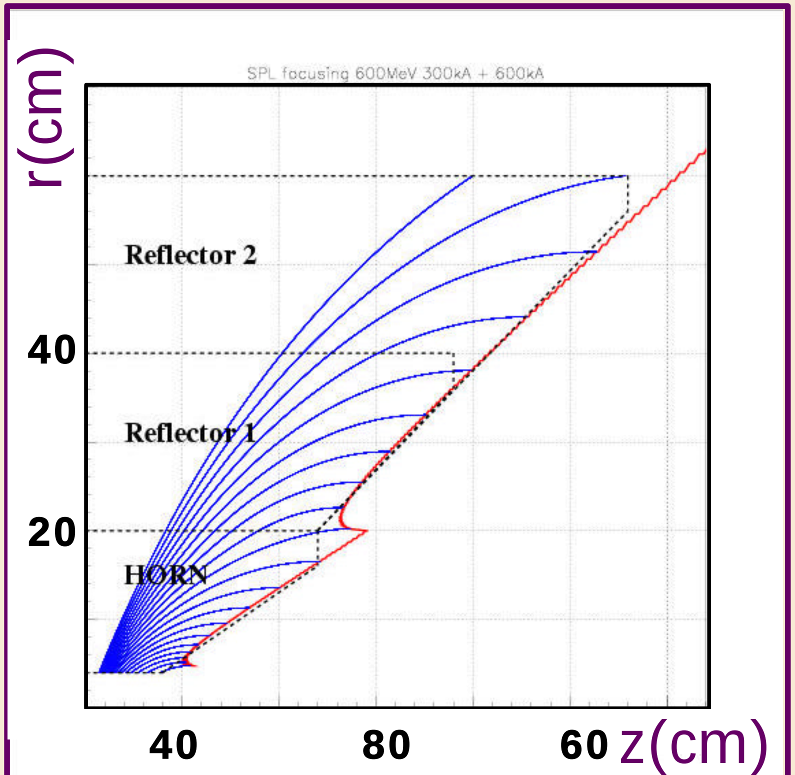
Pion production

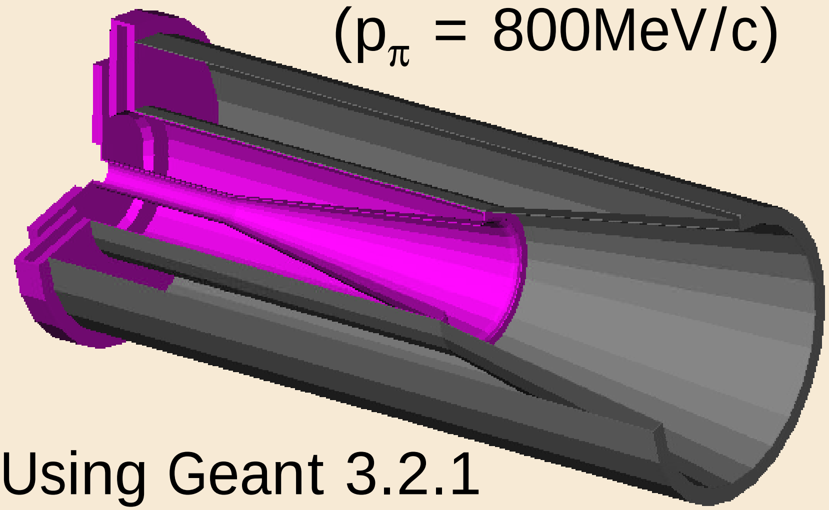


Pion production at the exit of the target
Comparison MARS FLUKA simulators

Horn simulation

- Drawing from the horn built at CERN
- Optimized for Super Beam :
  - E_ν ~ 260MeV (p_π = 600MeV/c)
  - E_ν ~ 300MeV (p_π = 800MeV/c)



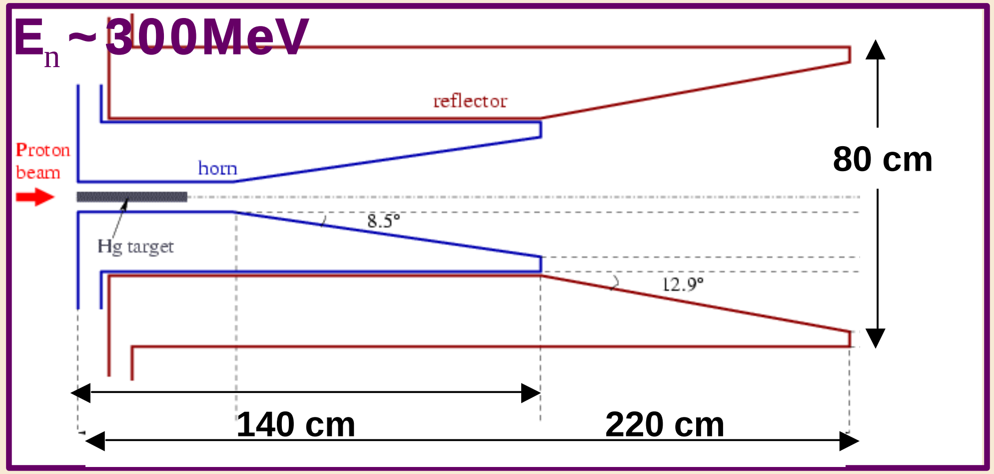


- Using Geant 3.2.1

NuFact-Note 138

Horn design parameter

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



E_ν~260MeV
E_π~600MeV

HORN	
inner radius	3.4cm
neck length	40cm
outer radius	20.5cm
total length	120cm
REFLECTOR	
outer radius	40cm
total length	190cm

E_ν~300MeV
E_π~800MeV

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

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Decay Tunnel Parameters

- Length
  - modify purity
  - L=10m, 20m, 40m and 60m have been tested.
  - 10m$\rightarrow$40m
    - ν_μ , $\overline{\nu}_\mu$ + 50% to 70%
    - ν_e , $\overline{\nu}_e$ + 50% to 100%
  - 40m$\rightarrow$60m
    - ν_μ , $\overline{\nu}_\mu$ + 5%
    - ν_e , $\overline{\nu}_e$ + 20%
- 40m seems better

- Radius
  - modify acceptance
  - R=1m, 1.5m and 2m have been Tested
  - 1m $\rightarrow$2m (L=40)
    - ν_μ , $\overline{\nu}_\mu$ +50%
    - ν_e , $\overline{\nu}_e$ +50% to 70%
- 2m seems better

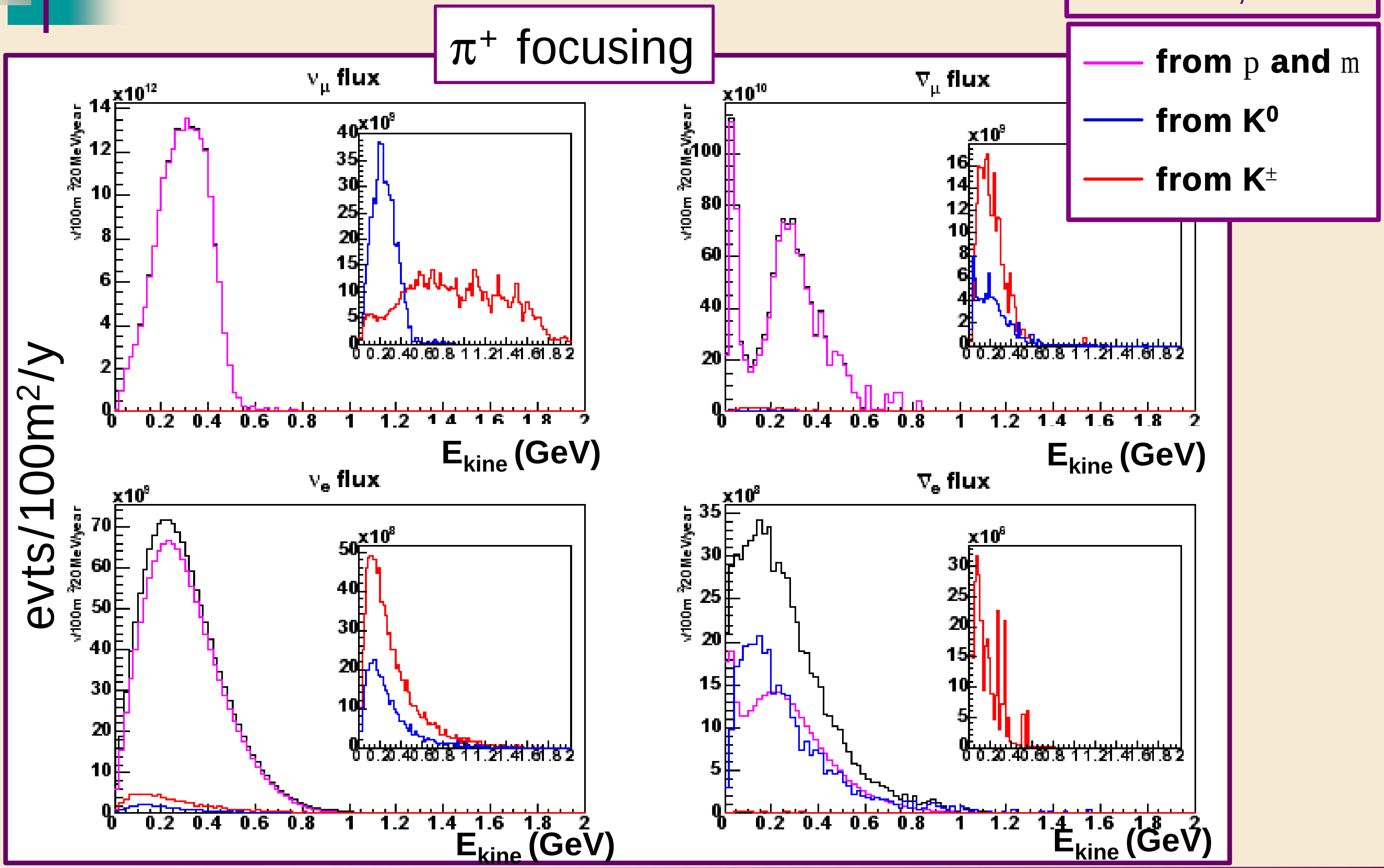
This results have been checked on sensitivity to θ_{13} and δ_{CP}

Flux calculation

- Low energy → Small boost → low focusing
- Need a high number of events (~10^{15} evts!!!)
- Use probability (M. Donega thesis approach)
  - Each time a pion, a muon, or a kaon is decayed by Geant, compute the probability for the neutrino to reach the detector
  - Use this probability as a weight, and fill an histogram with the neutrino energy
  - New → There are few kaons therfore a kaon produced in the target is duplicated many times: *~100.*
  - Gives neutrino spectrum.

Neutrino Flux 100km away

E_k=3.5GeV
E_ν ~300MeV
L = 40m,R=2m



q_{13} and d_{CP} Sensitivity computation

- Use Mauro Mezzetto's private code.
- detector:
  - Water Cerenkov
  - 440 kt
  - at Fréjus (130 km from CERN)
- Run:
  - 5 years π^+
  - 1 year π^+ + 4 years π^-
  - 2 years π^+ + 8 years π^-

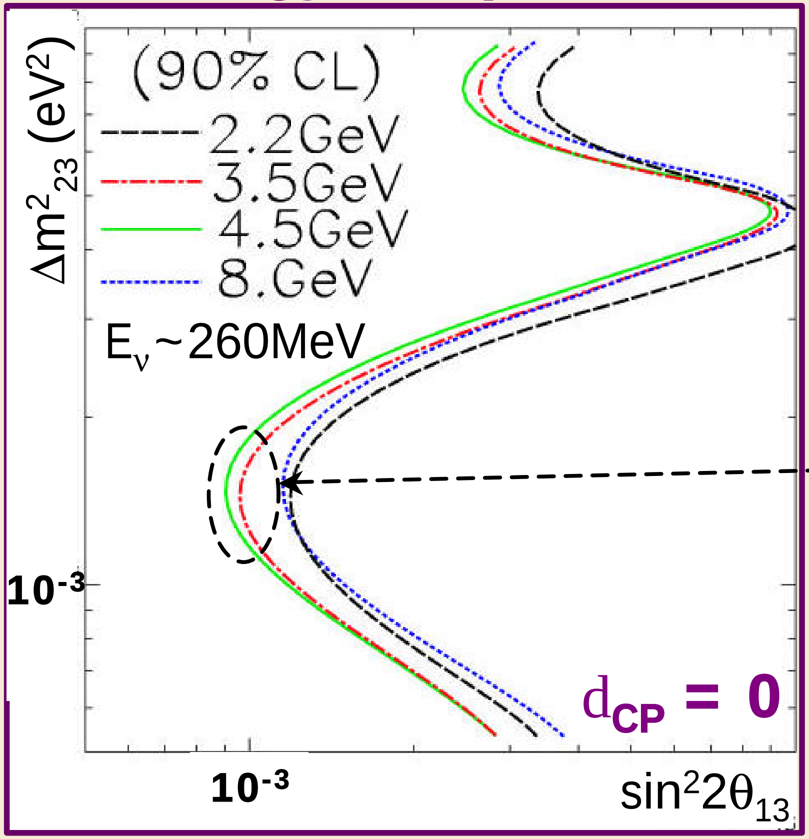
Same duration

Same statistics

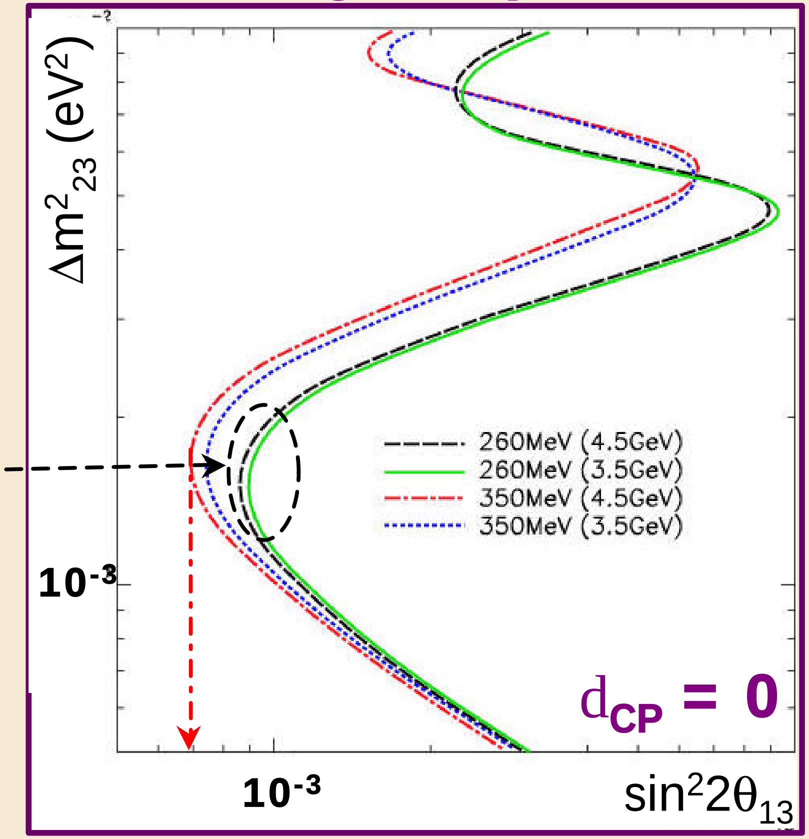
- Computed with δ_{CP}=0 (standard benchmark) and θ_{13} = 0
- other parameters...
  - $\Delta m_{23} = 2.5\ 10^{-3} eV^2$
  - $\Delta m_{12} = 7.1\ 10^{-5} eV^2$
  - $\sin^2 2\theta_{23} = 1.0$
  - $\sin^2 2\theta_{12} = 0.82$

5 years positive focusing

Energy comparison



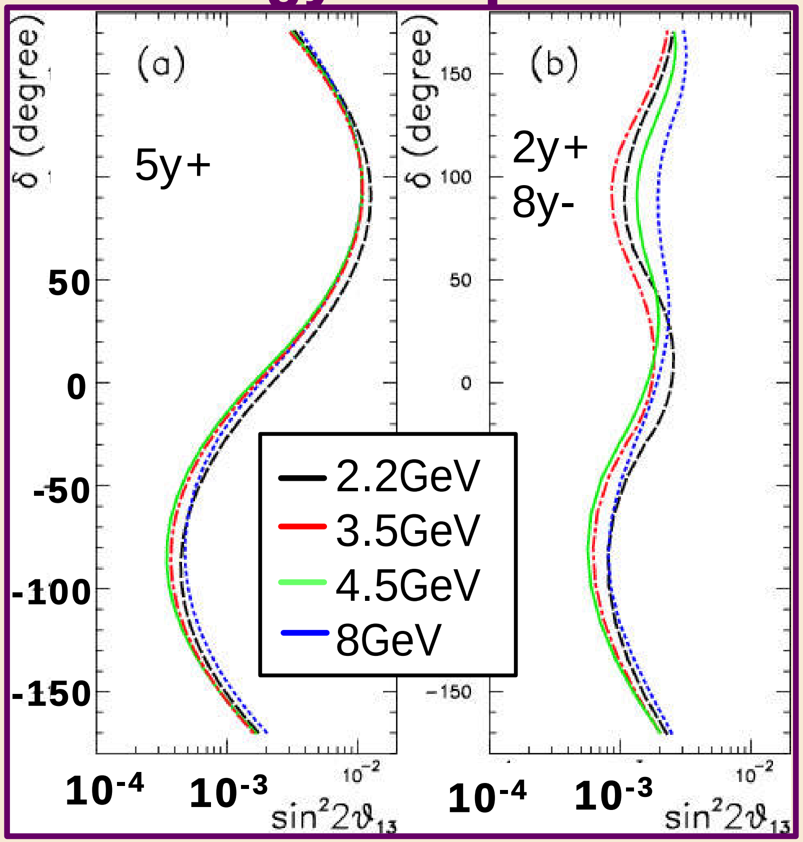
Focusing comparison



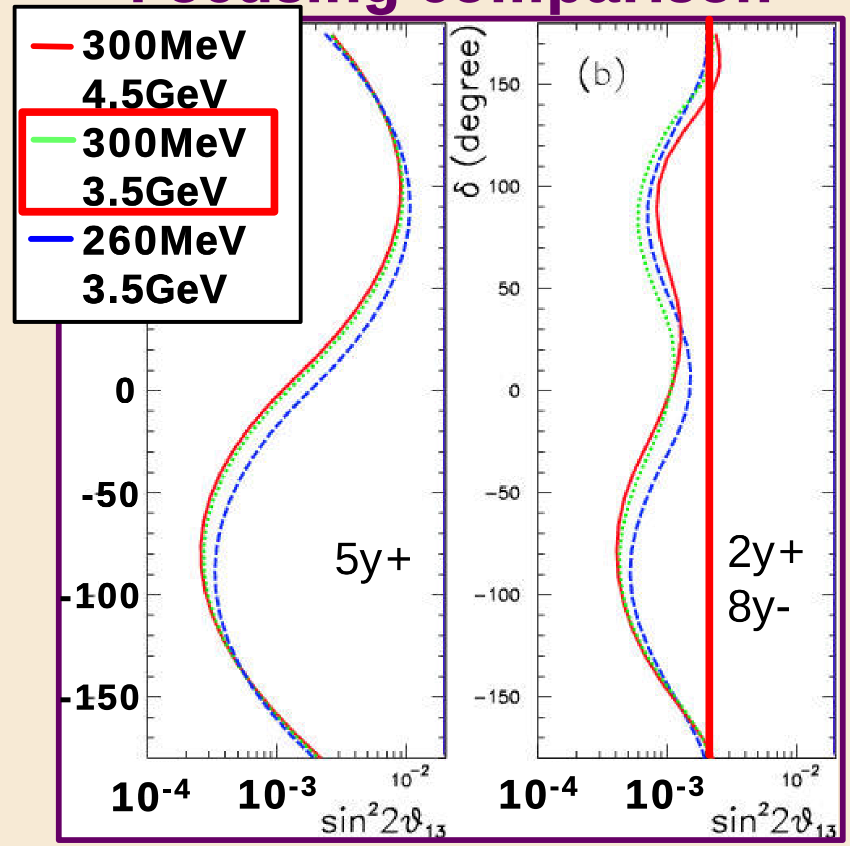
Best | tunnel : 40m long
2m radius | E_k = 4.5GeV
E_ν=300MeV | **$\sin^2 2q_{13} > 7.1\ 10^{-4}$**

positive focusing vs 10 years mixed scenario.

Energy comparison

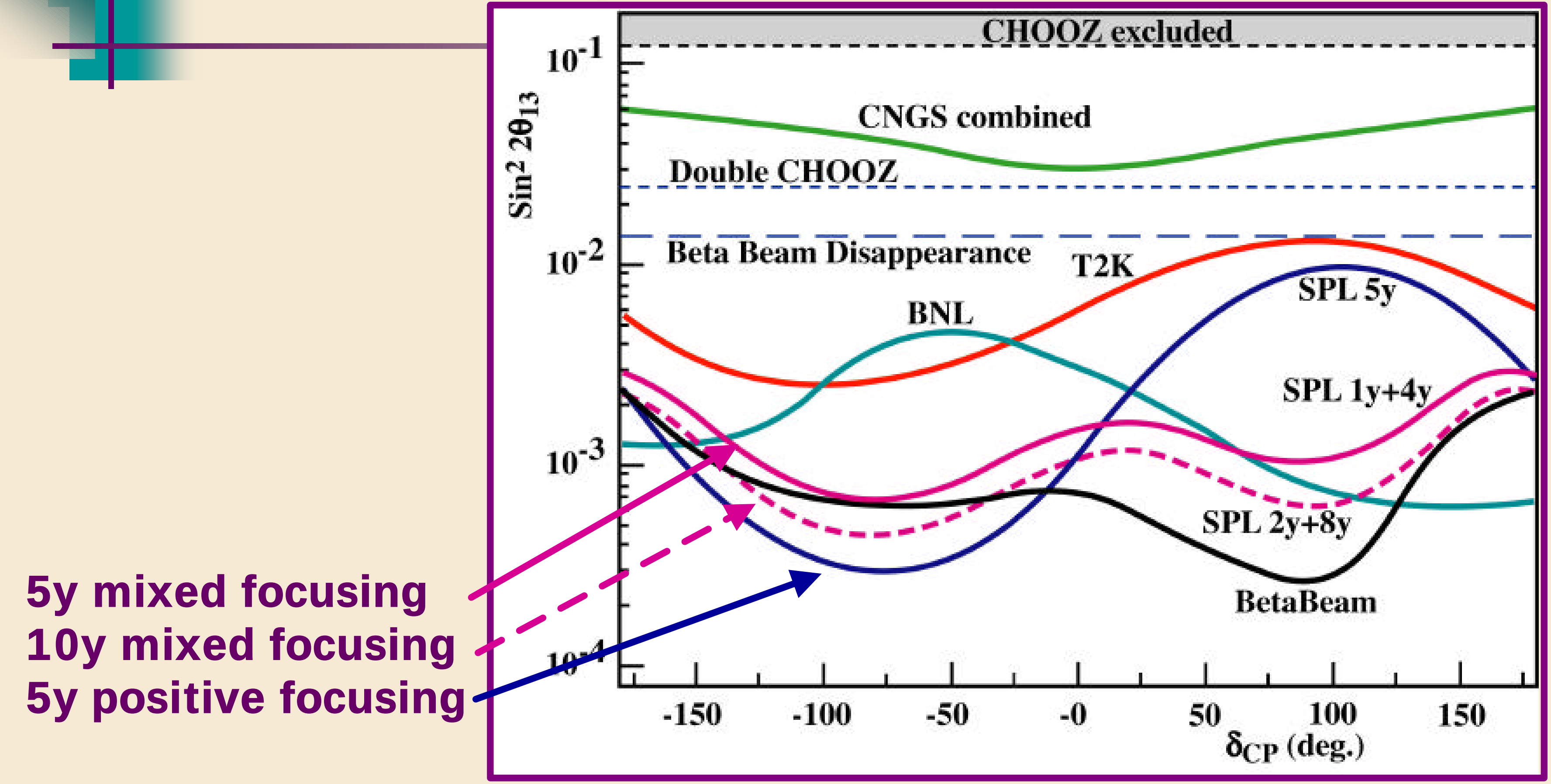


Focusing comparison



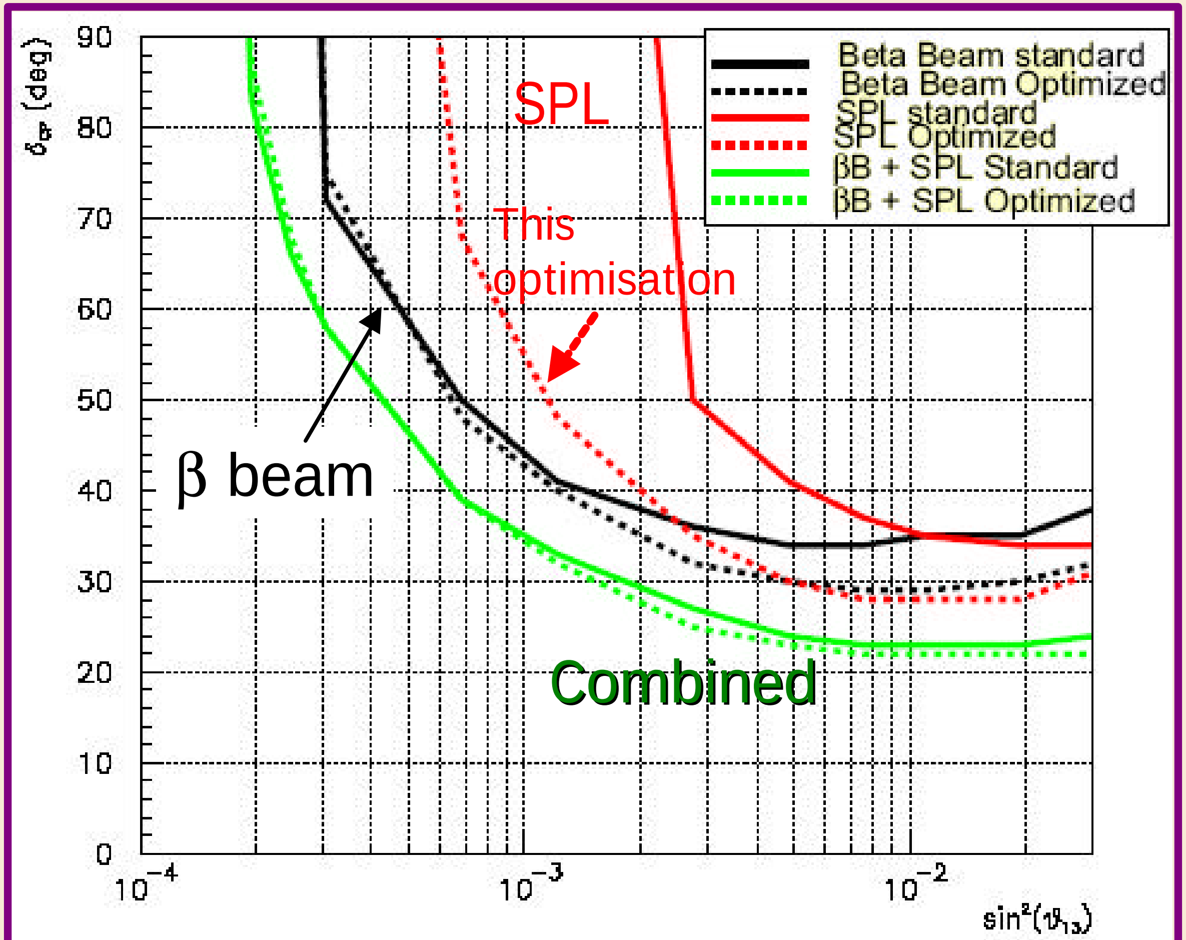
Best | tunnel : 40m long
2m radius | E_k = 3.5GeV
E_ν=300MeV | $\sin^2 2q_{13} > 2.02\ 10^{-3}$
90%CL

General comparison.



- for 10 years in mixed focusing, sensitivity around θ_{13}~1°
- Clear complementarily between positive scenario and βbeam (δ_{CP}>0)

Super Beam & beta Beam



3σ discovery potential curves

M. Mezzetto
Villars SPSC 04

Conclusion

- Higher proton energy is better!
  - sensitivity to θ_{13} +25%! (fixed tunnel, 2.2GeV$\rightarrow$3.5GeV)
- θ_{13} sensitivity, in the worse δ_{CP} case:
  - down to 1.3° with the 10y mixed scenario
  - down to 1.6° with the 5y mixed scenario
    - E_p = 3.5GeV, E_ν~300MeV
    - L=40m, R=2m
- Can measure δ_{CP}!