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β - beams

Beyond the baseline scenario

Baseline scenario

Based on present expertise and/or reasonable / conservative extrapolations

Inputs

- Ion production by pulsed ECR
- Use of PS/SPS with present performances and availability
- Use a mean cycle of 8 seconds

Scenario

- 1 single "EURISOL" target for He^6 and Ne^{18}
- Collect ions during 1 second every 8 seconds
- Store ion bunches in PS during 1 s.
- Accelerate in PS to $\gamma \sim 10$ in 1.2 s.
- Transfer to SPS and accelerate to $\gamma \sim 100$
- Inject in decay ring every 8 seconds

Ion losses in the baseline scenario

		LOSS FACTOR
① Ion production	1s — 7s — 1s — 7s	8
② Ion decays during collection in PS		1.4
③ Ion decays during PS acceleration		1.4
④ Transfer losses		2
		32

to be compared to Mats' estimate of 35

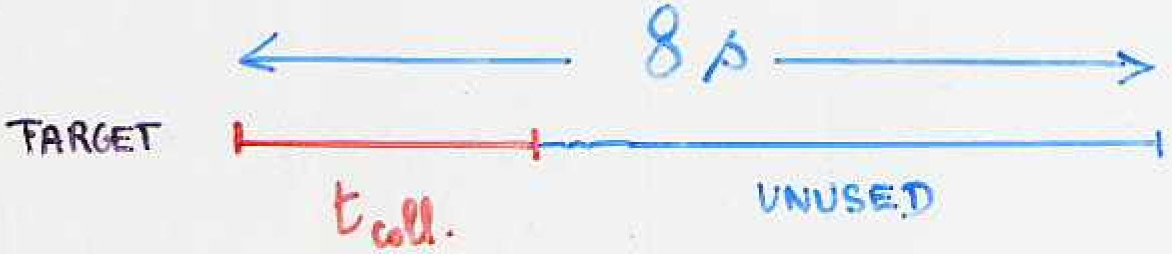
Question = How to improve?

3+4 = New faster PS (1.2 s → 0.1 s)

gain > 1.4 (+ better PS→SPS transfer)

1+2 = • Improve target yield (R & D) and/or number of targets
• Reduce overall cycle
• Increase collection time.

Increasing collection time



target producing f ions per second with ion lifetime $= \tau$

$$n_{col} = f\tau\left(1 - e^{-t_{col}/\tau}\right)$$

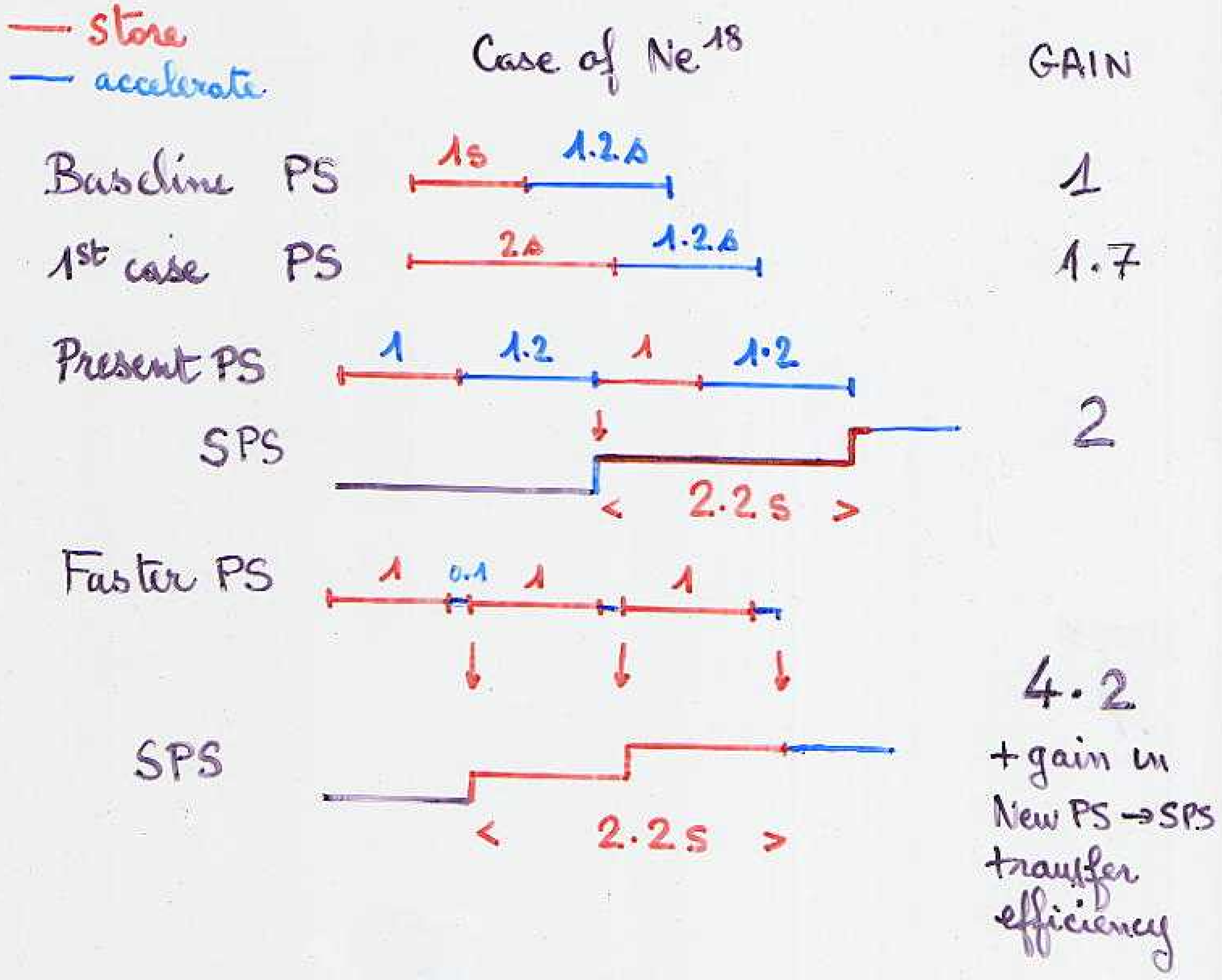
	t_{col}	He ($\tau = 1.15$ s) $n_{col}/f\tau$	Ne ($\tau = 2.45$ s) $n_{col}/f\tau$
Baseline scenario	1 s	0.58	0.33
	2 s	0.82 (1.4)	0.56 (1.7)
	3 s	0.92 (1.6)	0.71 (2.15)
	4 s		0.80 (2.4)

Sizeable improvement factors!
grow more slowly than t_{col}
because of decays.

Can we be smarter?

⇒ Transfer waiting time to high energy to avoid decay losses

⇒ Store ions in a "flat bottom" plateau at SPS before acceleration



Factor ≥ 5 gain in Ne^{18}!

(with the same 8 s cycle)

The physics case

- Baseline scenario:

  He^6: $\bar{\nu}_e$ flux $2.1\ 10^{18}/(10^7 s)$

  3 targets Ne^{18}: ν_e flux $0.35\ 10^{18}/(10^7 s)$

- Detector performances

  Hypothesis: Decay ring contains both ion species ⇒ Above numbers have to be divided by 2.

  But good for systematics

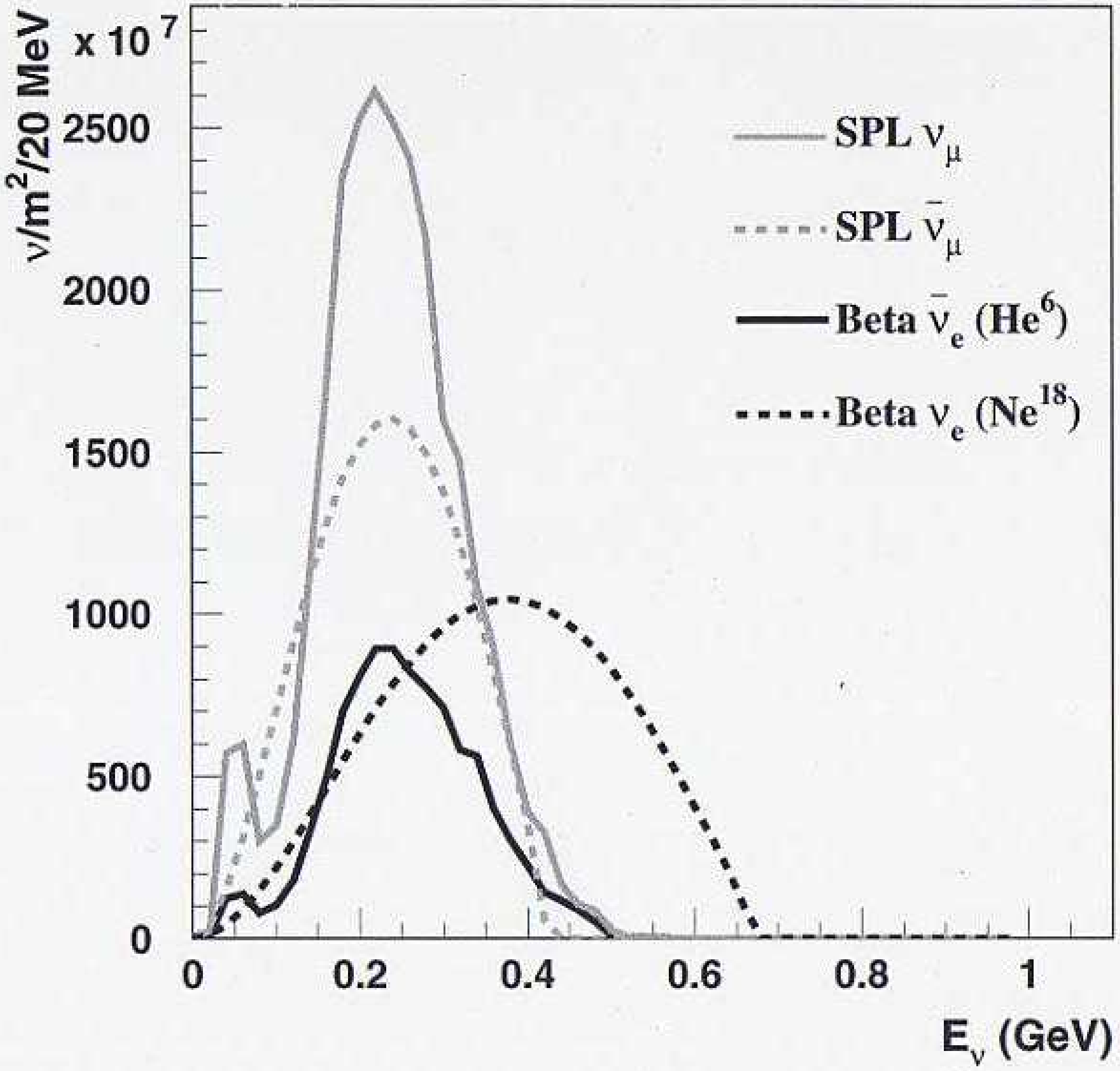
  Implies $\gamma_{He} = 60$ and $\gamma_{Ne} = 100$

  Fluxes used for study

He^6	$2.9\ 10^{18}$	2.8	Improvem.t factors compared to baseline scenario
Ne^{18}	$1.1\ 10^{18}$	6.3	

These factors are realistic

There is even a good probability that we will do better!

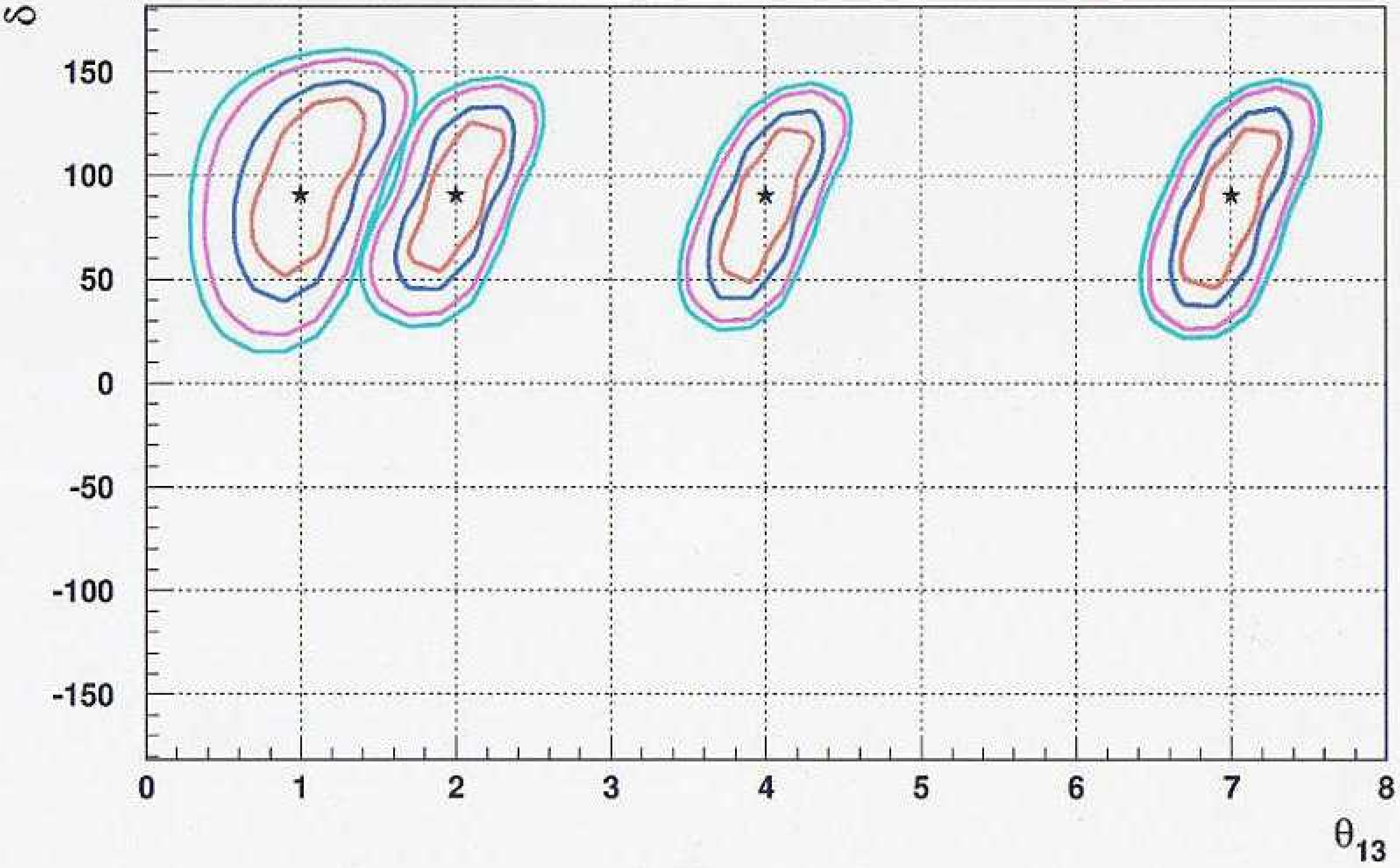


	Fluxes $\nu/m^2 \cdot$ year	$\langle E_\nu \rangle$ GeV
$\bar{\nu}_e$	$2\ 10^{11}$	0.24
ν_e	$1.9\ 10^{11}$	0.36
ν_μ	$4.8\ 10^{11}$	0.27
$\bar{\nu}_\mu$	$3.3\ 10^{11}$	0.25

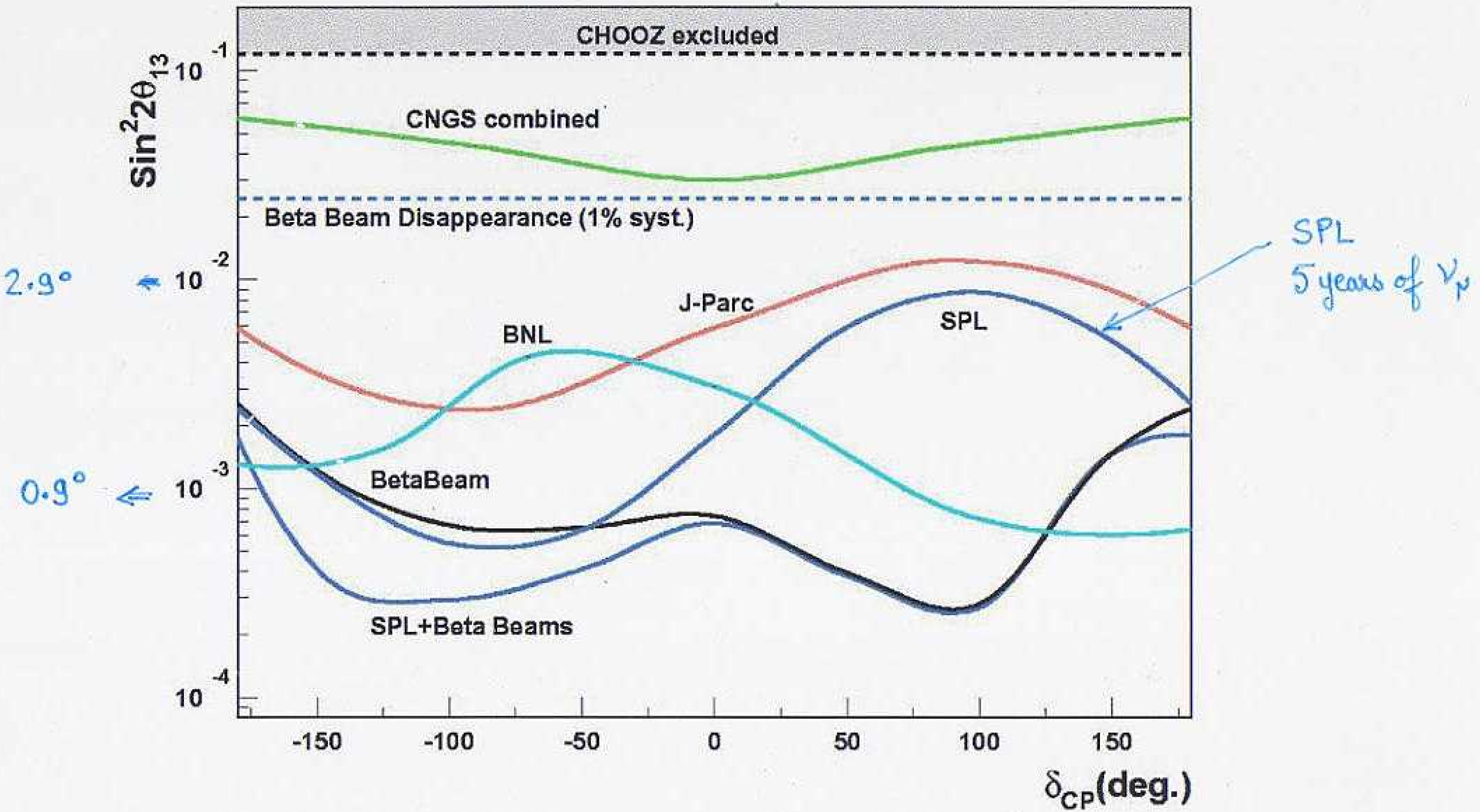
Fits to θ_{13} and δ after 10 years (β beam only)

INPUTS $\left.\begin{array}{l}\delta m^2_{12} = 7.1\ 10^{-5}\ eV^2 \\ \sin^2 2\theta_{12} = 0.8\end{array}\right\}\pm 10\%$ $\left\{\begin{array}{l}\delta m^2_{23} = 2.5\ 10^{-3}\ eV^2 \pm 5\% \\ \sin^2 2\theta_{23} = 1 \pm 1\%\end{array}\right.$

NO DEGENERACIES (except sign interchange between δ and Δm^2_{13})



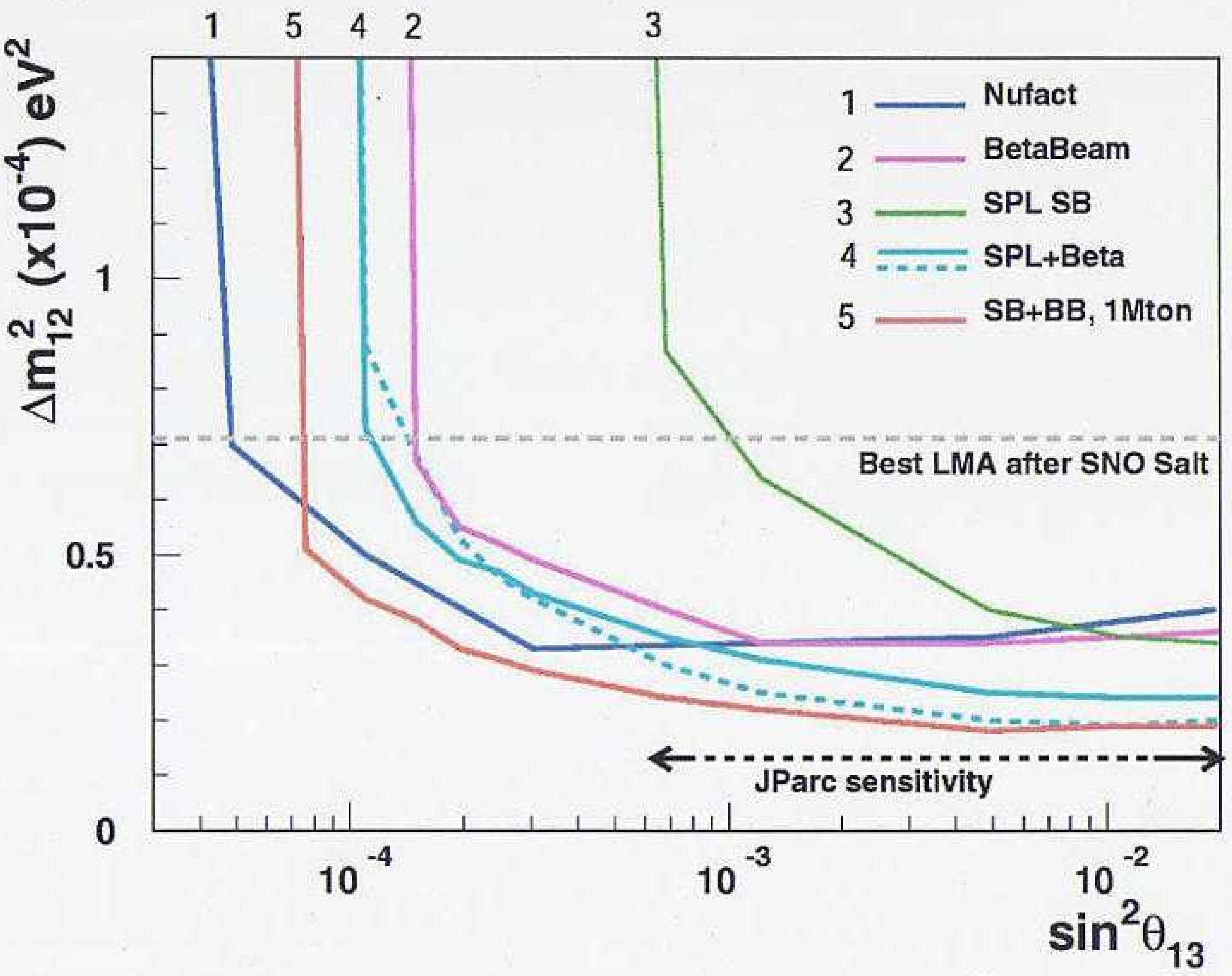
Curves are
1σ
90%
99%
3σ



CHOOZ excluded
CNGS combined
Beta Beam Disappearance (1% syst.)
J-Parc
BNL
SPL
BetaBeam
SPL+Beta Beams
$Sin^2 2\theta_{13}$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
-150
-100
-50
0
50
100
150
δ_{CP}(deg.)
2.9°
0.9°
SPL
5 years of ν_μ

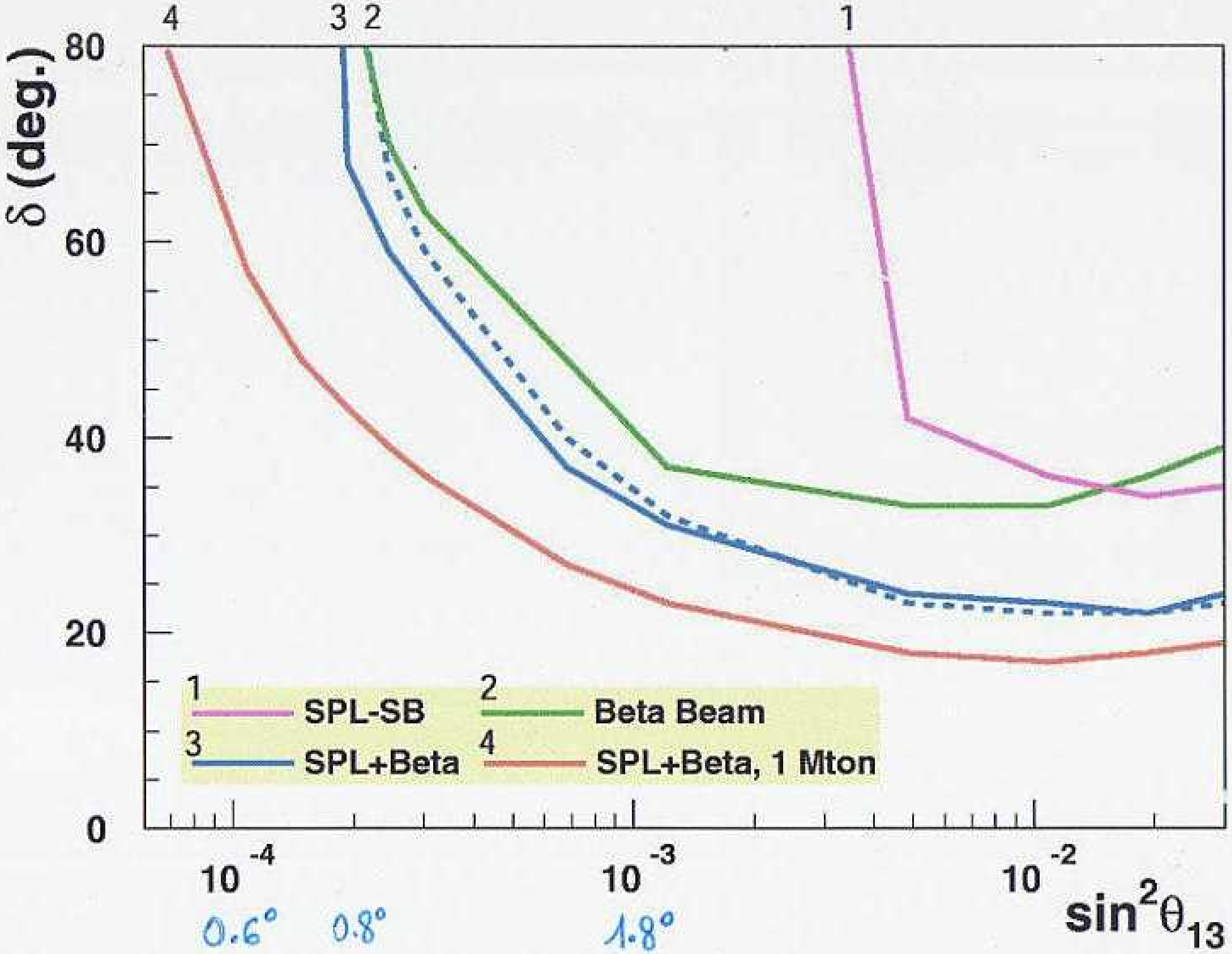
4400 kT-year

99% CL sensitivity to maximal CP violation



--- : $\text{sign}(\Delta m^2_{13}) = -1$

δ discovery potential at 3σ



Conclusion

The baseline scenario leaves room for sizeable improvements.

Improvement factors used in the "physics case" seem realistic

Superbeam + β beam + Frejus is world unique and shows strong advantages:

- Best sensitivity
- Redundancy (allowing for systematics control)
- Attractive schedule if not delayed