A BASELINE BETA-BEAM

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on behalf of the
Beta-beam Study Group

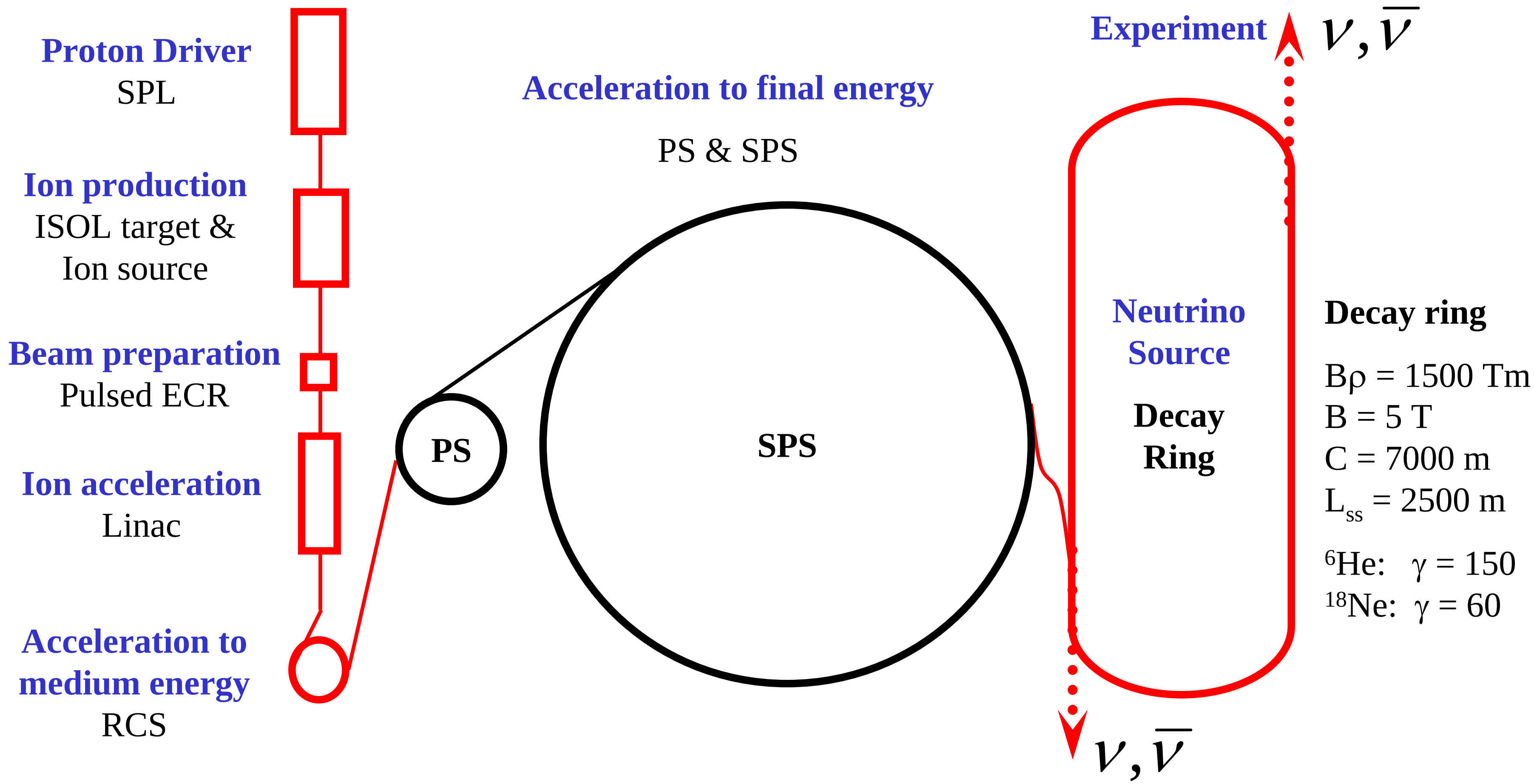
http://cern.ch/beta-beam/

General

- Critical analyses of flux from a the baseline betabeam facility
  - Bottom up and compare it to required flux
- This is not a basis for new physics calculations but an input to the design study
  - For internal discussion at the betabeam task meeting

Beta-beam baseline design

Ion production **Acceleration** **Neutrino source**



Main parameters (1)

- **Factors influencing ion choice**
  - **Need to produce reasonable amounts of ions.**
  - **Noble gases preferred - simple diffusion out of target, gaseous at room temperature.**
  - **Not too short half-life to get reasonable intensities.**
  - **Not too long half-life as otherwise no decay at high energy.**
  - **Avoid potentially dangerous and long-lived decay products.**

- **Best compromise**
  - **Helium-6 to produce antineutrinos:** $^{6}_{2}He \rightarrow ^{6}_{3}Li\ e^{-}\ \bar{\nu}$

    Average $E_{cms} = 1.937$ MeV
  - **Neon-18 to produce neutrinos:** $^{18}_{10}Ne \rightarrow ^{18}_{9}F\ e^{+}\nu$

    Average $E_{cms} = 1.86$ MeV

FLUX

The Design Study is aiming for:

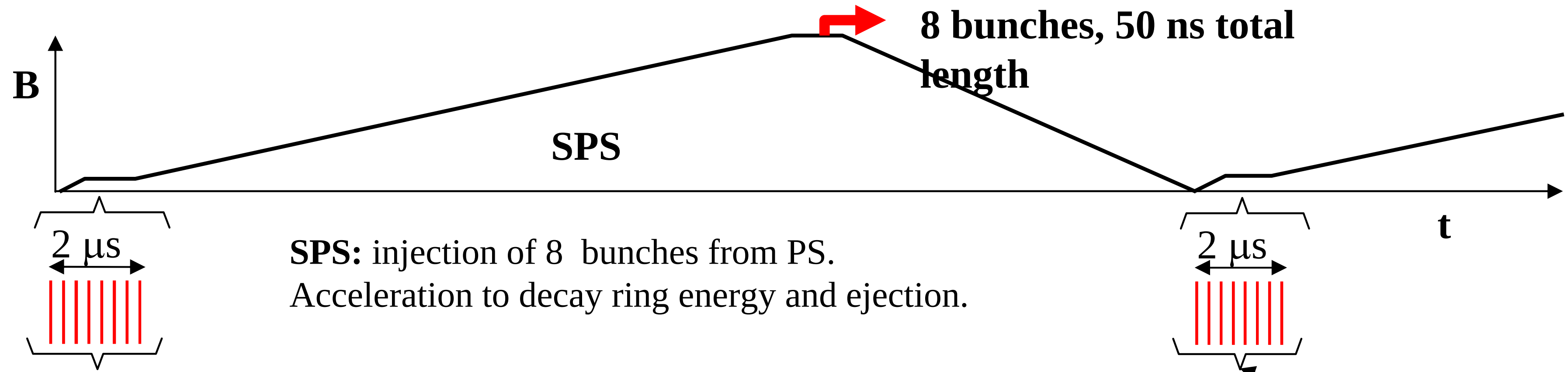
- A beta-beam facility that will run for a "normalized" year of 10^7 seconds
- An integrated flux of 10 10^{18} anti-neutrinos (^{6}He) and 5 10^{18} neutrinos (^{18}Ne) in ten years running at γ=100

with

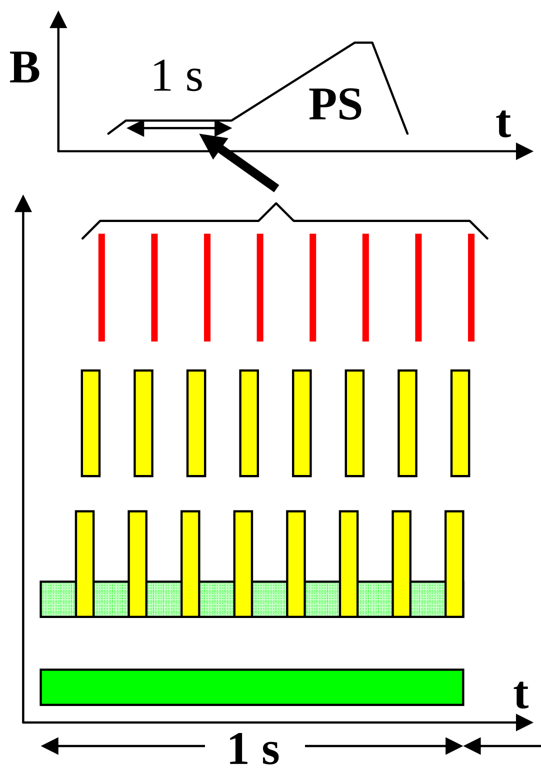
- 2 10^{13} ^{6}He atoms per second
- 8 10^{11} ^{18}Neatoms per second

injected as neutral gas into the ECR source.

From dc to very short bunches



SPS: injection of 8 bunches from PS.
Acceleration to decay ring energy and ejection.



PS: 1 s flat bottom with 16 injections. Acceleration in ~1 s to ~86.7 Tm..

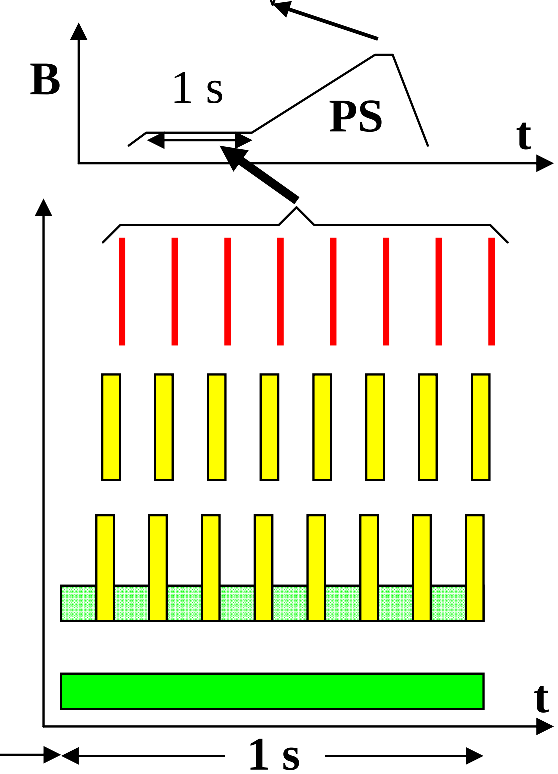
RCS: further bunching to ~100 ns
Acceleration to ~ 8 Tm.
16 repetitions during 1 s.

Post accelerator linac:
acceleration to ~100 MeV/u.
16 repetitions during 1 s.

60 GHz ECR: accumulation for 1/16 s ejection of fully stripped ~50 µs pulse.
16 batches during 1 s.

Target: dc production during 1 s.

7 s



Intensities, 6He

Machine	Total Intensity out (10^{12})	Comment
Source	20	DC pulse, Ions extracted for 1 second
ECR	1.16934	Ions accumulated for 60 ms, 99% of all 6He ions in highest charge state, 50 microseconds pulse length
RCS inj	0.582144	Multi-turn injection with 50% efficiency
RCS	0.570254	Acceleration in 1/32 seconds to top magnetic rigidity of 8 Tm
PS inj	6.82254	Accumulation of 16 bunches during 1 second
PS	5.75908	Acceleration in 0.8 seconds to top magnetic rigidity of 86.7 Tm and merging to 8 bunches.
SPS	5.43662	Acceleration to gamma=100 in 2.54 seconds and ejection to decay ring of all 8 bunches (total cycle time 6 seconds)
Decay ring	58.1137	Total intensity in 8 bunches of 50/8 ns length each at gamma=100 will result in a duty cycle of 0.0022. Maximum number of merges = 15.

Intensities, 18Ne

Machine	Total Intensity out (10^{10})	Comment
Source	80	DC pulse, Ions extracted for 1 second
ECR	1.42222	Ions accumulated for 60 ms, 30% of all 18Ne ions in one dominant charge state, 50 microseconds pulse length
RCS inj	0.709635	Multi-turn injection with 50% efficiency
RCS	0.703569	Acceleration in 1/32 seconds to top magnetic rigidity of 8 Tm
PS inj	10.093	Accumulation of 16 bunches during 1 second.
PS	9.57532	Acceleration in 0.8 seconds to top magnetic rigidity of 86.7 Tm and merging to 8 bunches.
SPS	9.45197	Acceleration to gamma=100 in 1.42 seconds and ejection to decay ring of all 8 bunches (total cycle time 3.6 seconds)
Decay ring	11.8514	8 bunches of 50/8 ns length each will at gamma=100 result in a duty cycle of 0.0022. Maximum number of merges = 15.

Flux

This will result in an annual flux of

- 1.77 10^{18} anti-neutrinos (^{6}He)
- 1.90 10^{16} neutrinos (^{18}Ne)

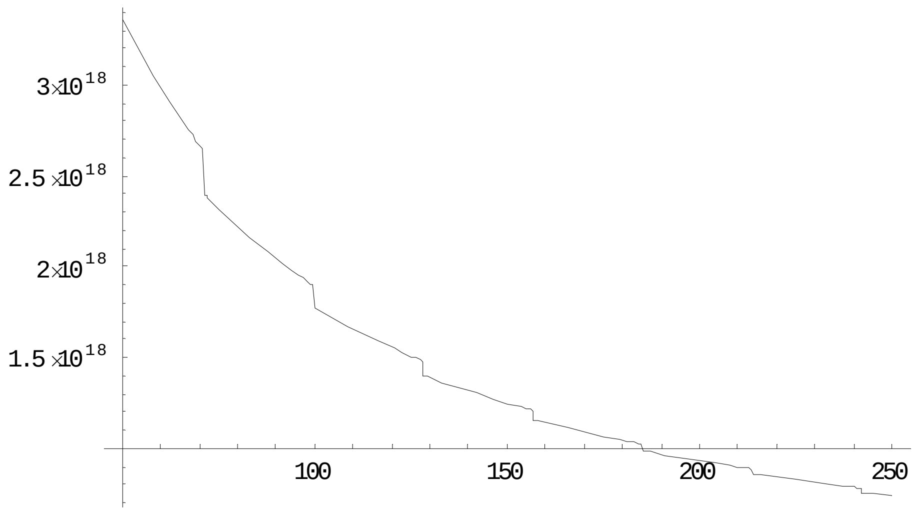
At gamma=100 which is

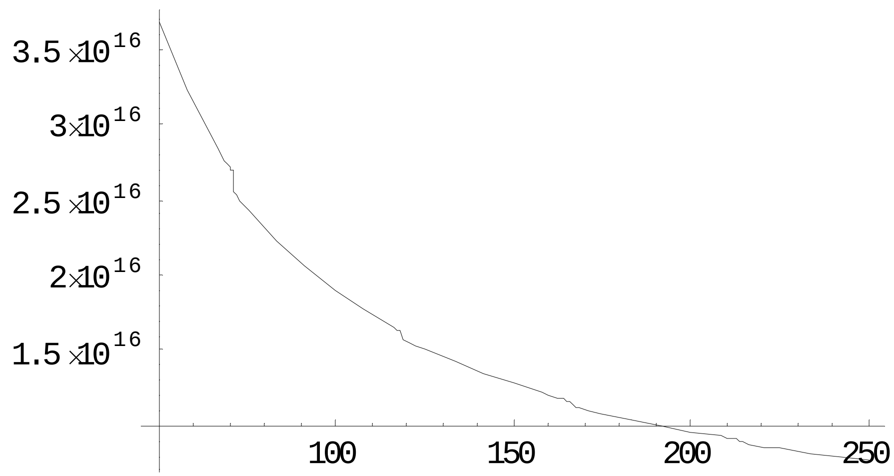
- 1.77/2 = 88 % of required anti-neutrino flux
- 0.019/1 =1.9 % of required neutrino flux

What can we do?

- The parameters that we can act on are:
  - Accelerate more than one charge state for Neon
  - Make the Neon run longer
  - Increase production of Neon
  - Change gamma
  - Introduce a longer accumulation stage after the RCS
    - In the PS or in a dedicated storage ring
  - Accept a larger duty factor
  - Change isotope

Flux as a function of gamma

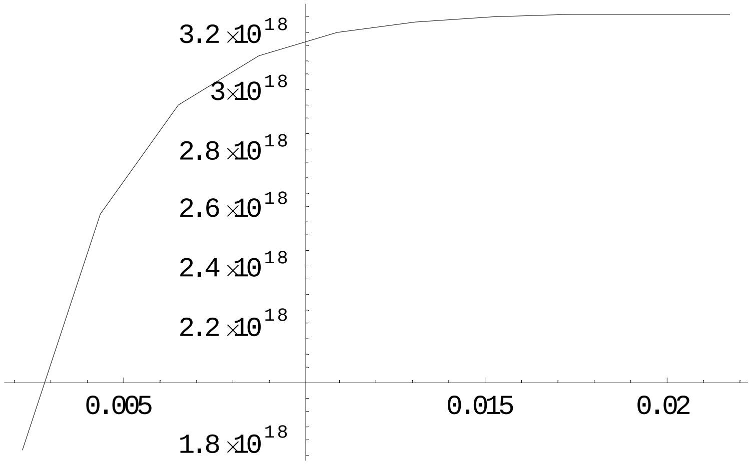




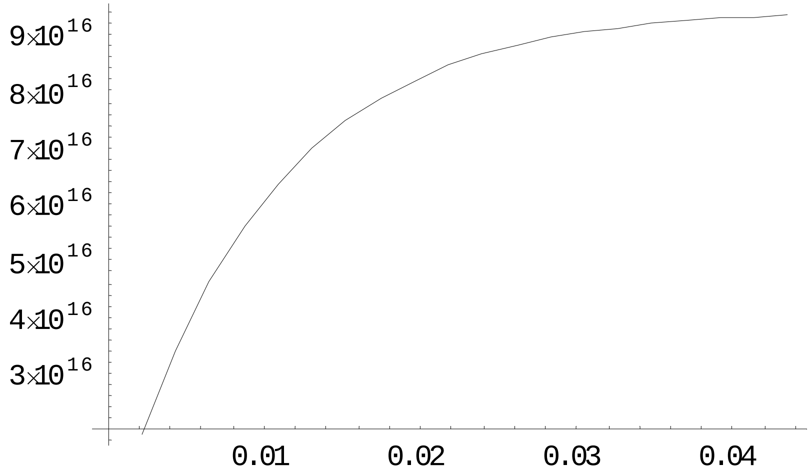
^{6}He

^{18}Ne

Flux as a function of duty cycle

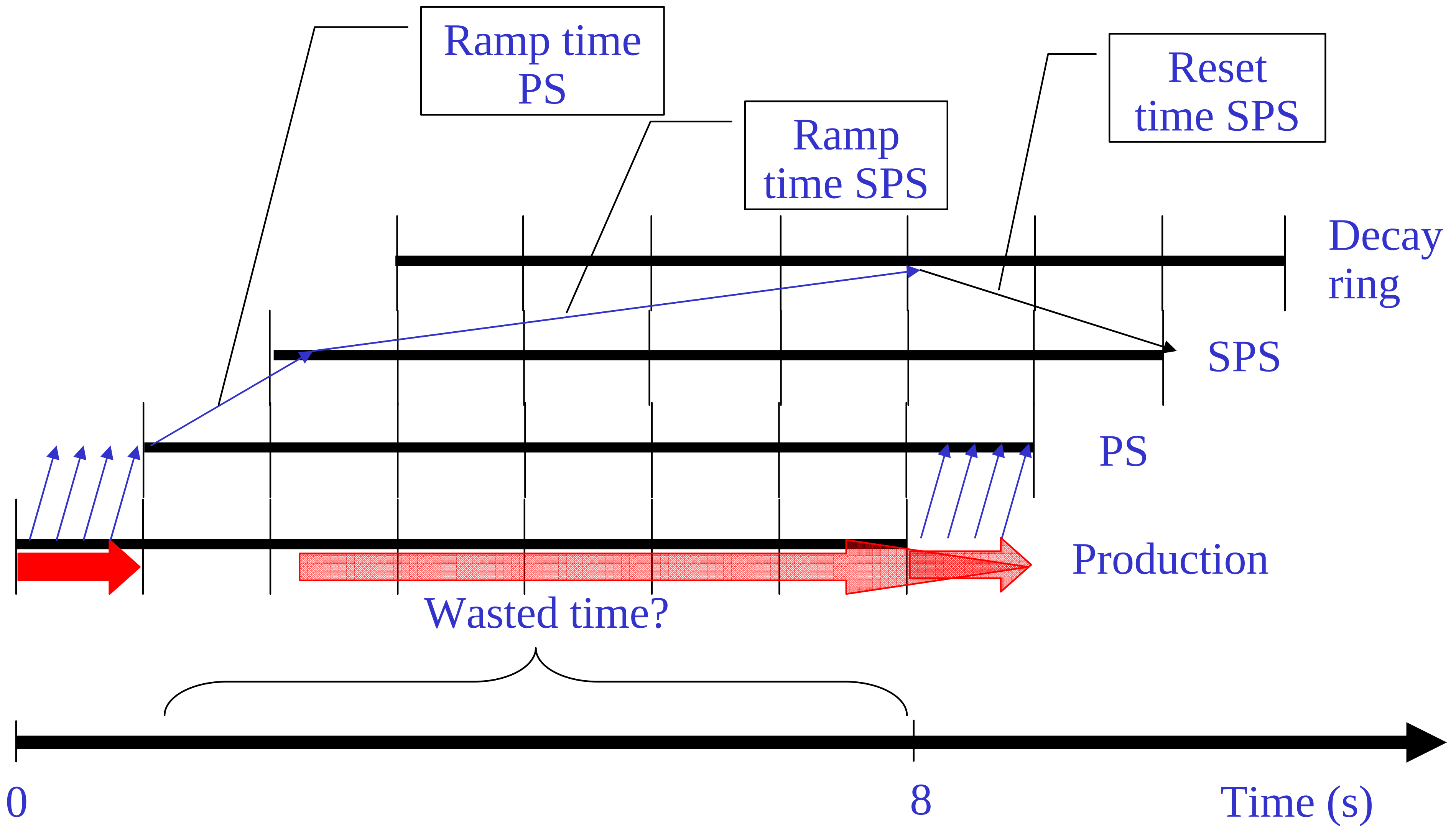


^{6}He

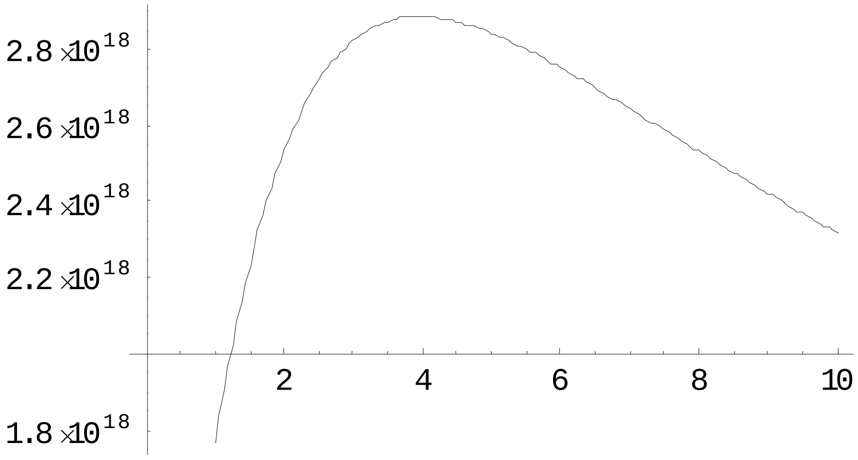


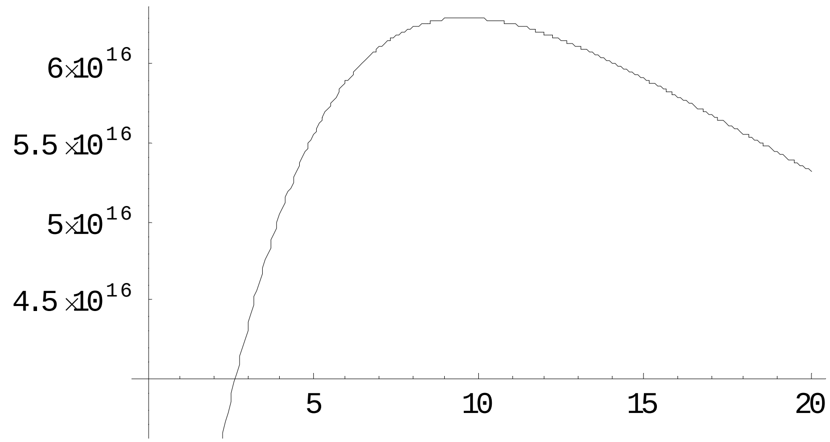
^{18}Ne

Wasted time or accumulation time?



Flux as a function of accumulation time (seconds) in the PS

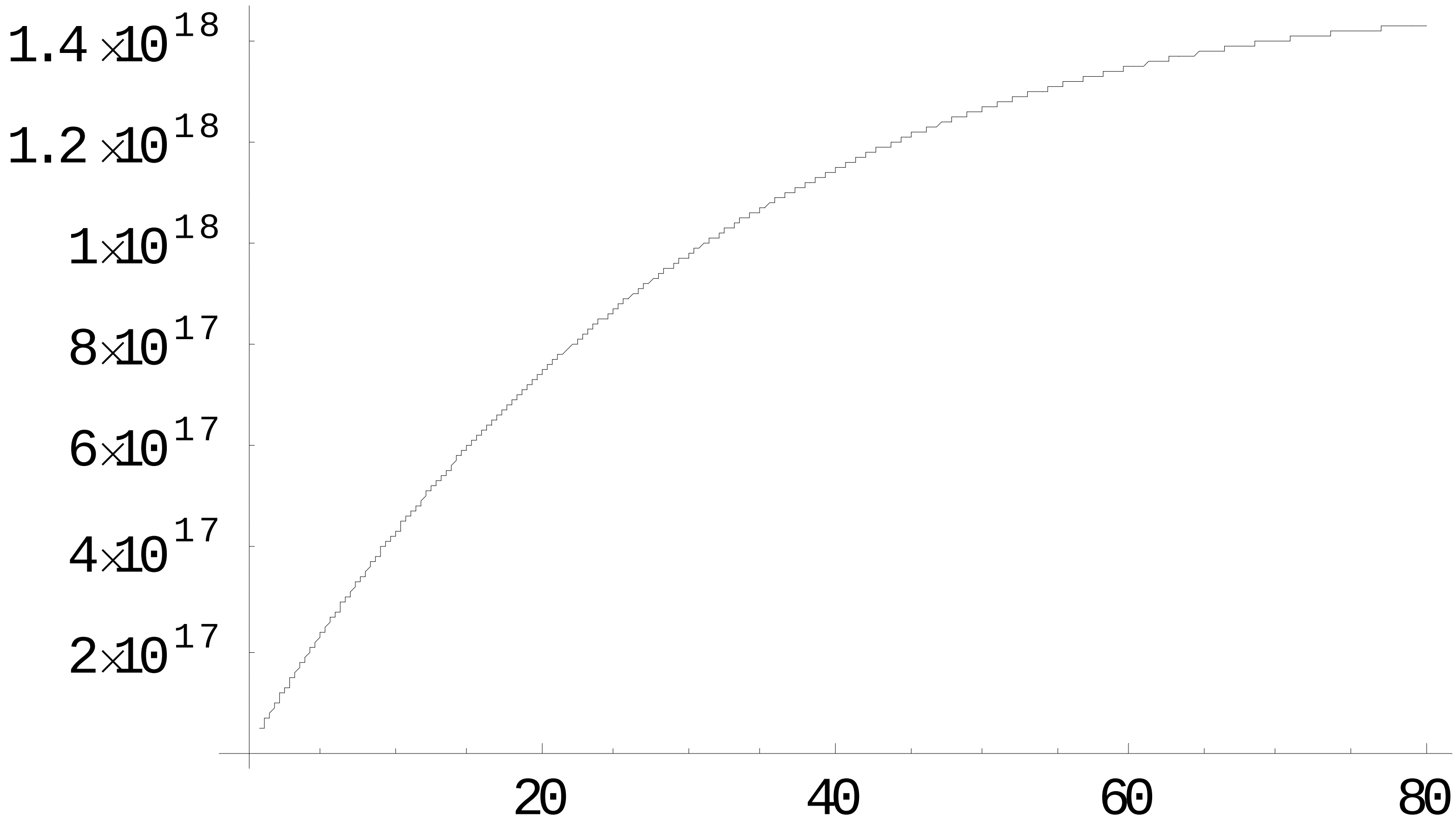




^{6}He

^{18}Ne

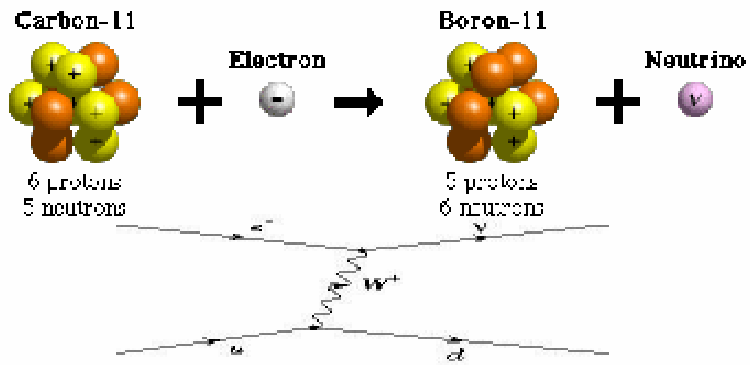
19 Ne, 20 times more!
Flux as a function of accumulation time (s)



(for one charge state of ^{19}Ne)

EC or the dream of monochromatic neutrino beams

Electron capture:

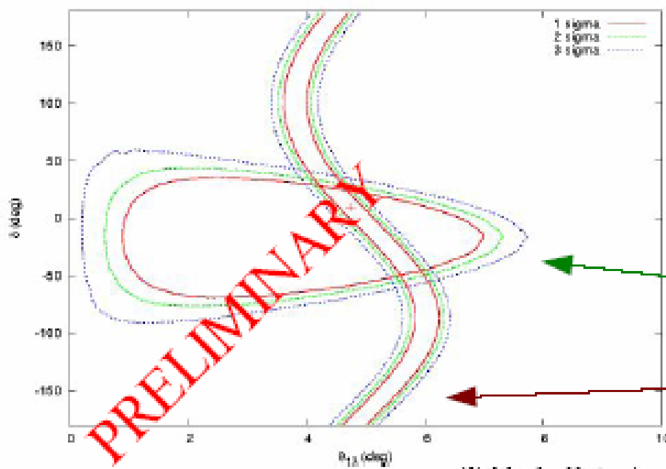


flux: $$\frac{d^2N_\nu}{dSdE} = \frac{\Gamma_{ec}}{\Gamma}\frac{N_{ions}}{\pi L^2}\gamma^2\delta(E-2\gamma E_0)$$

branching ratio

very *peaked* energy spectrum (practically monochromatic)

Setup very similar to a beta-beam



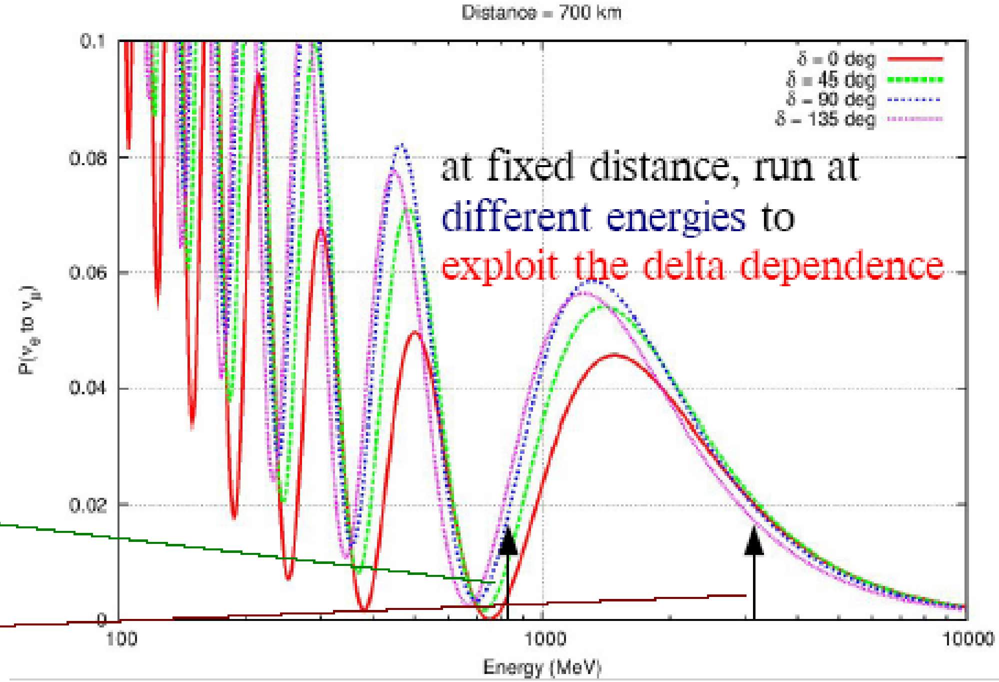


Table 1: Beta decay properties of some rare-earth nuclei around ^{146}Gd

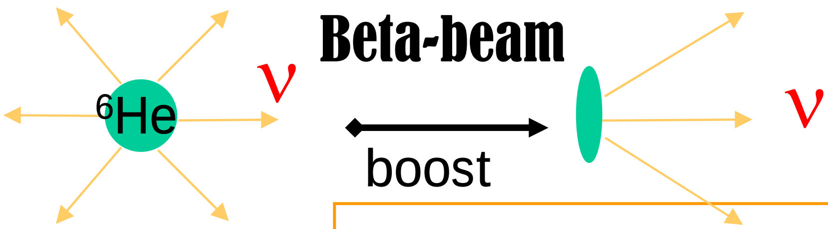
Decay	$T_{1/2}$	$I_{\beta GR}$(%)	B(GT)($g_A^2/4\pi$)	E_{GR}(keV)	Γ_{GR}(keV)	$E_\nu=Q_{EC}-E_{GR}$(keV)	ΔE_ν(keV)	EC/β^+(%)	Comments
$^{148}Dy \rightarrow {}^{148}Tb$	3.1 m	96.2	0.46	620.2	—	2061.8	—	96/4	excellent!
$^{150}Dy \rightarrow {}^{150}Tb$	7.17 m	100	0.32	397.2	—	1396.8	—	99.9/0.1	36% goes α
$^{152}Tm\ 2^- \rightarrow {}^{152}Er$	8.0 s	≈50	0.48	≈4300	≈520	≈4400	≈520	45/55	
$^{150}Ho\ 2^- \rightarrow {}^{150}Dy$	72.0 s	≈56	0.25	≈4400	≈400	≈3000	≈400	77/33	

Proposed: (^{148}Dy, ^{150}Dy rows)

EC

- The vacuum half life in the decay ring is in the order of 10s of minutes for partly stripped ions (RHIC)
- The production of rare earth metals is good from robust Ta foil targets
- The detector is reduced to a counting experiment
  - NO energy reconstruction

LOW-ENERGY BETA-BEAMS



C. Volpe, hep-ph/0303222
Journ. Phys. G. 30(2004)L1

THE PROPOSAL

To exploit the beta-beam concept to produce intense and pure low-energy neutrino beams.

PHYSICS POTENTIAL

- Neutrino-nucleus interaction studies for particle, nuclear physics, astrophysics (nucleosynthesis).

  Important for neutrinoless double-beta decay.

  C. Volpe, hep-ph/0501233

- Neutrino properties, like ν magnetic moment.

Comments

- Well-established beta-beam baseline scenario.
  - We need to address the flux issue for ^{18}Ne
    - Accumulation time, charge state(s), production and length of run
- Baseline study should result in a credible conceptual design report.
  - We need a "STUDY 1" for the beta-beam to be considered a credible alternative to super beams and neutrino factories
  - New ideas welcome but the design study cannot (and will not) deviate from the given flux target values and the chosen baseline
  - Parameter list to be frozen by end of 2005
- News from NNN05: World committee to advice on site for a future Mton detector
  - Choice strongly influenced by available beams
- Recent new ideas promise a fascinating continuation into further developments beyond (but based on) the ongoing EURISOL (beta-beam) DS
  - Low energy beta-beam, EC beta-beam, High gamma beta-beam, etc.
- And this is probably only the beginning…