BETA-BEAM

Base-line design study within EURISOL

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on behalf of the
Beta-beam Study Group

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

Outline

- **Beta-beam baseline design**
  - The baseline scenario
  - Main parameters and choices
- **Ongoing work and recent results**
  - Asymmetric bunch merging for stacking in the decay ring.
  - Goals - Status
- **Conclusions**

History of beta-beams

- **Beta-beam proposal by Piero Zucchelli in 2002:**
  - *A novel concept for a neutrino factory: the beta-beam*, Phys. Let. B, 532 (2002) 166-172.

- **AIM: production of a pure beam of electron neutrinos (or antineutrinos) through the beta decay of radioactive ions circulating in a high-energy (γ~100) storage ring.**

- **First ideas on conceptual design of the accelerator complex presented at NuFact'02 ("The Beta-beam working group").**

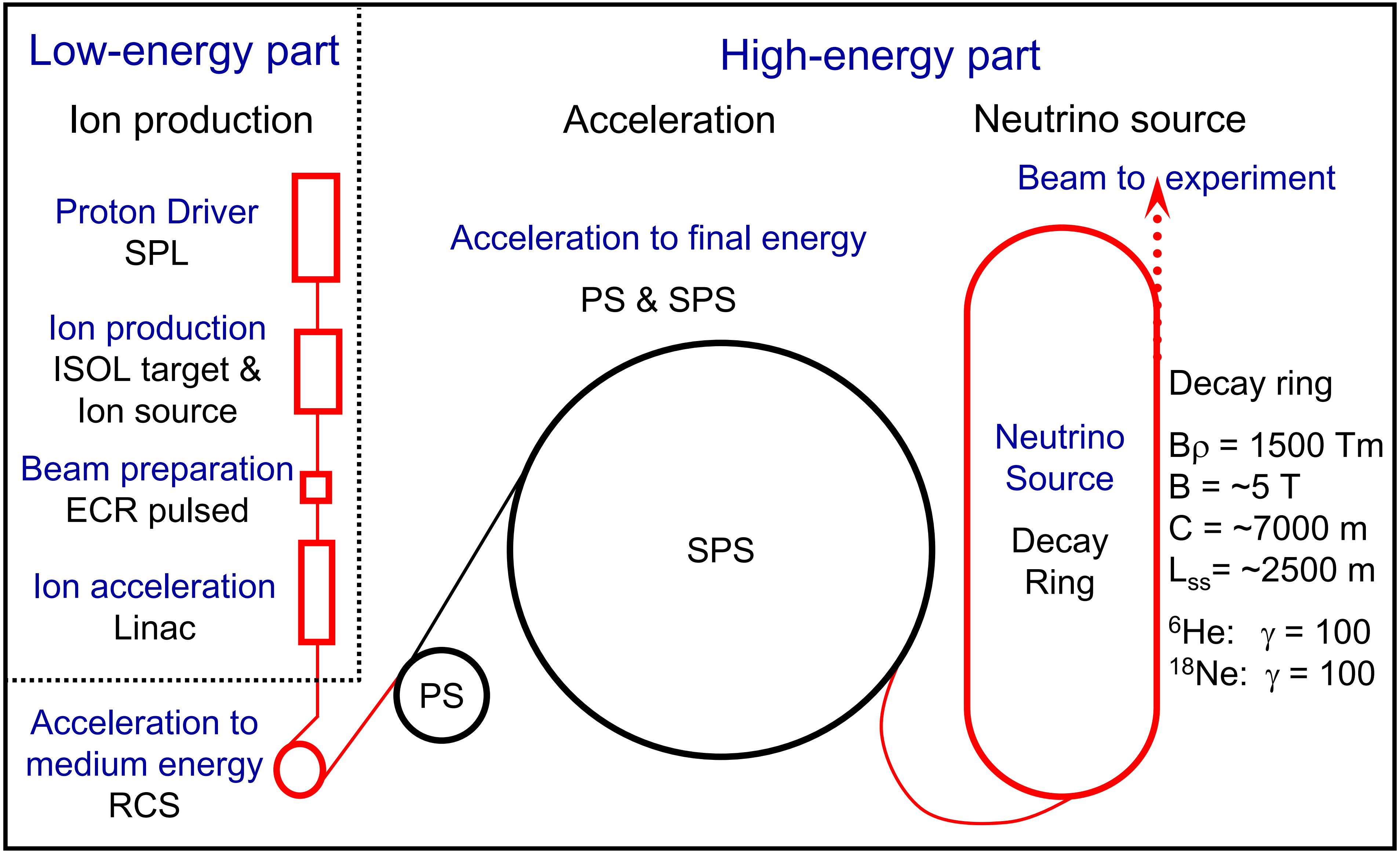
- **Conceptual design study for a Beta-beam complex within the EURISOL DS (6th framework programme of EU) 2005-2008/9.**

Beta-beam base line design

- **Strategy for the conceptual design study:**
  - Design should be based on known technology.
  - Avoid large number of technology jumps, requiring major and costly R&D efforts.
  - Re-use wherever possible existing infrastructure (i.e. accelerators) for the "first stage" base line design.

- **Major ingredients:**
  - ISOL technique for production of radioactive ions.
  - Use CERN PS and SPS accelerators for acceleration.

Beta-beam baseline design



Main parameters (1)

- Ion choice
  - Possibility to produce reasonable amounts of ions
  - Noble gases preferred - simple diffusion out of target, gas phase 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
  - ^{6}Helium^{2+} to produce antineutrinos:

$$ {}^{6}_{2}He \rightarrow {}^{6}_{3}Li\, e^{-}\, \bar{\nu} $$

$$ \text{Average } E_{cms} = 1.937 \text{ MeV} $$

  - ^{18}Neon^{10+} to produce neutrinos:

$$ {}^{18}_{10}Ne \rightarrow {}^{18}_{9}Fe\, e^{+}\, \nu $$

$$ \text{Average } E_{cms} = 1.86 \text{ MeV} $$

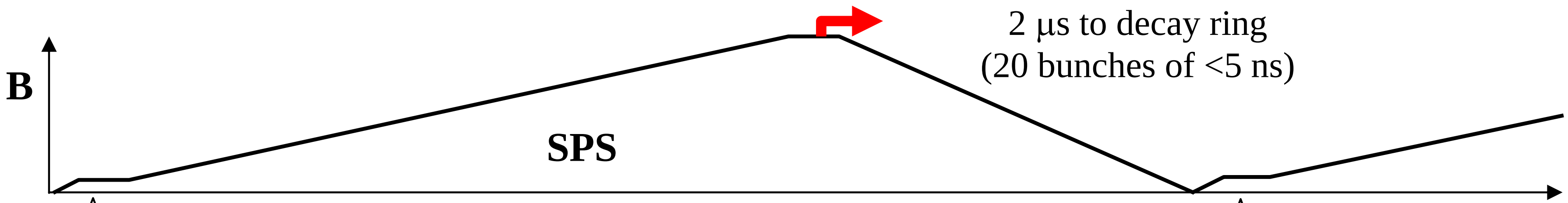
Main parameters (2)

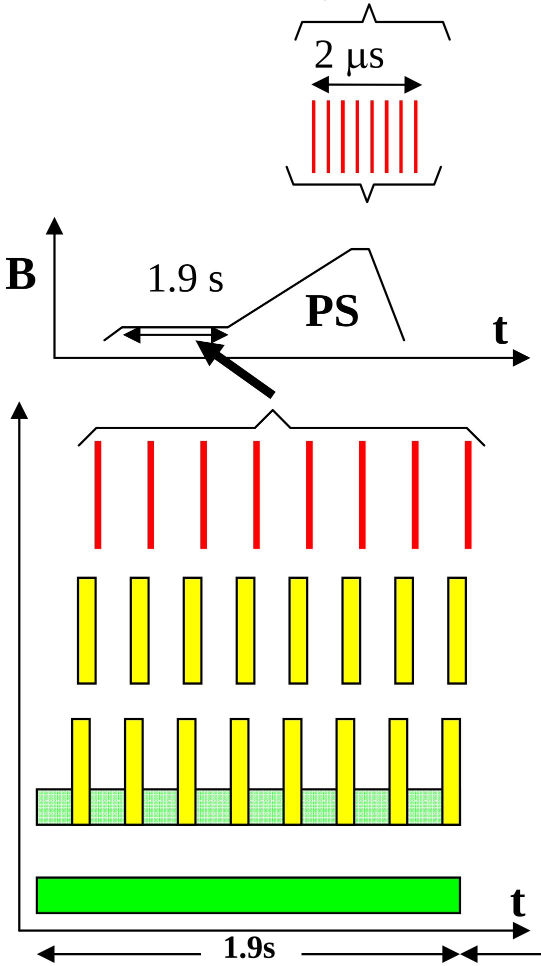
- Target values in the decay ring

^{6}Helium^{2+}		^{18}Neon^{10+} (single target)	
– Intensity (av.):	1.0×10^{14} ions	– Intensity (av.):	7.2×10^{13} ions
– Rel. gamma:	100	– Rel. gamma:	100

- The neutrino beam at the experiment has the “time stamp” of the circulating beam in the decay ring.
- The beam has to be concentrated in as few and as short bunches as possible to maximize the peak number of ions/nanosecond (background suppression).
- Aim for a duty factor of $\sim 10^{-3}$ -> this is a major design challenge!

From dc to very short bunches





SPS: injection of 20 bunches from PS.
Acceleration to decay ring energy and ejection.
Repetition time 6 s.

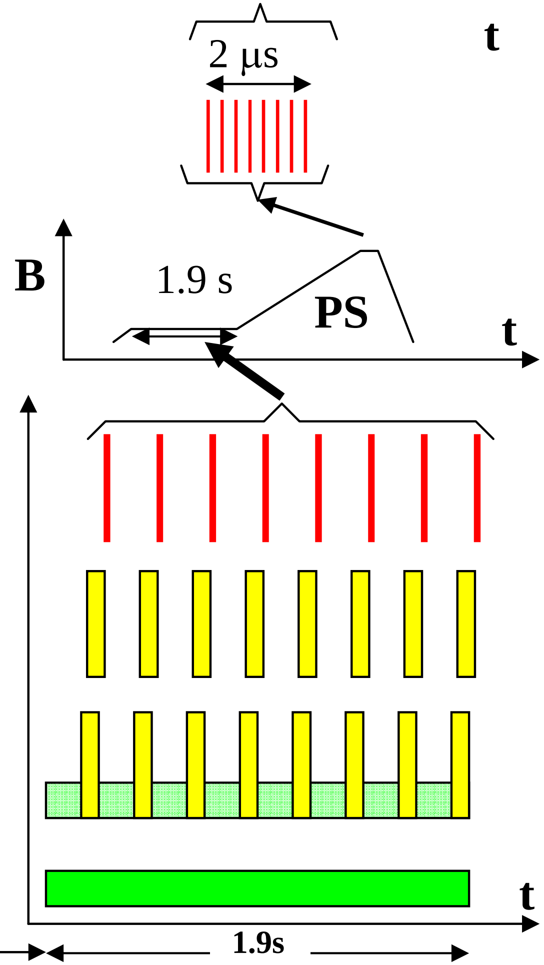
PS: 1.9 s flat bottom with 20 injections. Acceleration in 0.8 s to top energy.

RCS: further bunching to ~100 ns.
Acceleration to ~500 MeV/u.
10 Hz repetition rate.

Post accelerator linac:
acceleration to ~100 MeV/u.
20 repetitions during 1.9 s.

60 GHz ECR: accumulation for 0.1 s.
Ejection of fully stripped ~20 μs pulse.
20 batches during 1.9 s.

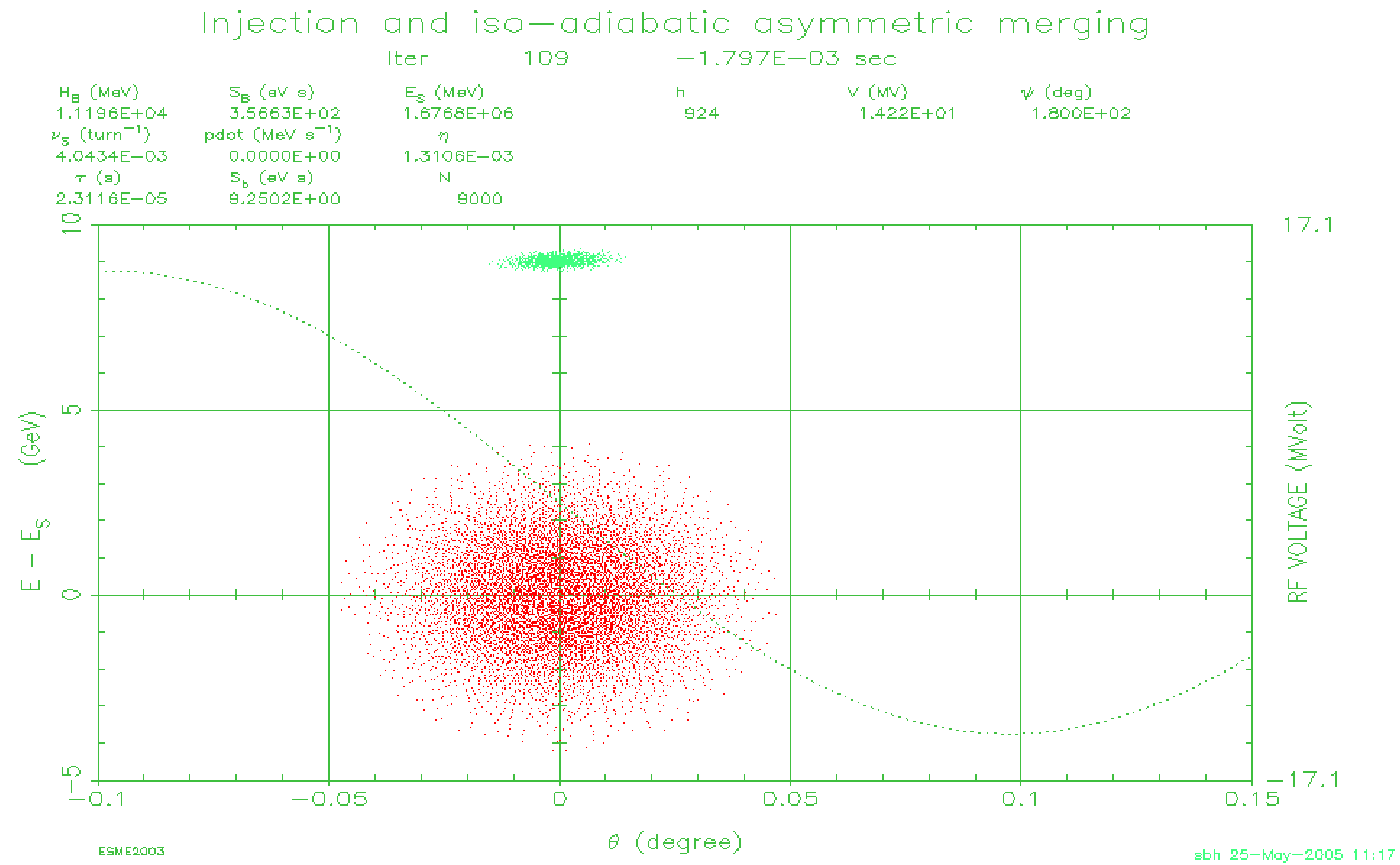
Target: dc production during 1.9 s.



Decay ring design aspects

- The ions have to be concentrated in very few very short bunches.
  - Suppression of atmospheric background via time structure.
- There is an absolute need for stacking in the decay ring.
  - Not enough flux from source and injection chain.
  - Life time is an order of magnitude larger than injector cycling (~120 s as compared to a few seconds for SPS cycling).
  - We need to stack at least over 10 to 15 injector cycles.
- No one of the established cooling methods can be used
  - Electron cooling is excluded because of the high electron beam energy and in any case far too long cooling times.
  - Stochastic cooling is excluded by the high bunch intensities.
- A new injection/merging technique was developed (asymmetric bunch pair merging in longitudinal phase space).

Simulation (in the SPS)



Goals - Status

- **For the base line design, the aims are (cf. Bouchez et al., NuFact'03):**
  - An annual rate of 2.9 10^{18} anti-neutrinos (^{6}He) along one straight section
  - An annual rate of 1.1 10^{18} neutrinos (^{18}Ne) at γ=100

  always for a "normalized" year of 10^{7} seconds.

- **The present status is (after 8 months of the 4-year design study):**
  - Antineutrino rate (and ^{6}He figures) have reached the design values but no safety margin is yet provided.
  - Neutrino rate (and ^{18}Ne figures) are one order of magnitude below the desired performance.

Challenges for the study

- **Production and beam preparation (esp. ^{18}Ne).**
  - Charge state distribution after ECR source.
- **The re-use of existing accelerators**
  - Cycling time,
  - Aperture limitations etc.
  - Energy ranges
  - Collimation and beam cleaning systems
- **General aspects:**
  - The small duty factor in the decay ring.
  - The activation from decay losses.
  - The high intensity ion bunches in the accelerator chain and decay ring

Conclusions

- **Beta-beam design study is advancing well, encouraging results obtained after only 8 months.**
- **Main efforts will now focus on 18Ne shortfall.**
- **Going beyond the base line design at a later stage with additional accumulation rings, and other new machines (green-field) may open the way to important performance enhancements.**