Beta-beams at Fermilab?

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Beta-beam???

- Proposed by Piero Zucchelli (ex CERN)
- Use radioactive nuclei to produce pure $\bar{\nu}_e$ (ν_e) neutrino beam
  - Production and acceleration easier than for muon-based scenarios.
  - Nuclei produce more events in the far detector for a given parent intensity.
  - Single flavor, well know energy spectrum.
- Combined with high intensity conventional neutrino beam (super-beam), physics reach is similar to muon neutrino factory.

[P. Zucchelli, Phys. Lett. B, 532 (2002) 166-172]

Why neutrinos?

- Unless we find a niche for the Tevatron (e.g BTev), it will not run much longer once the LHC turns on!
- The lab is already on the neutrino path (e.g. MiniBOONE, MINOS)!
- Booster is tired! New (high intensity) proton source coming?

The challenge

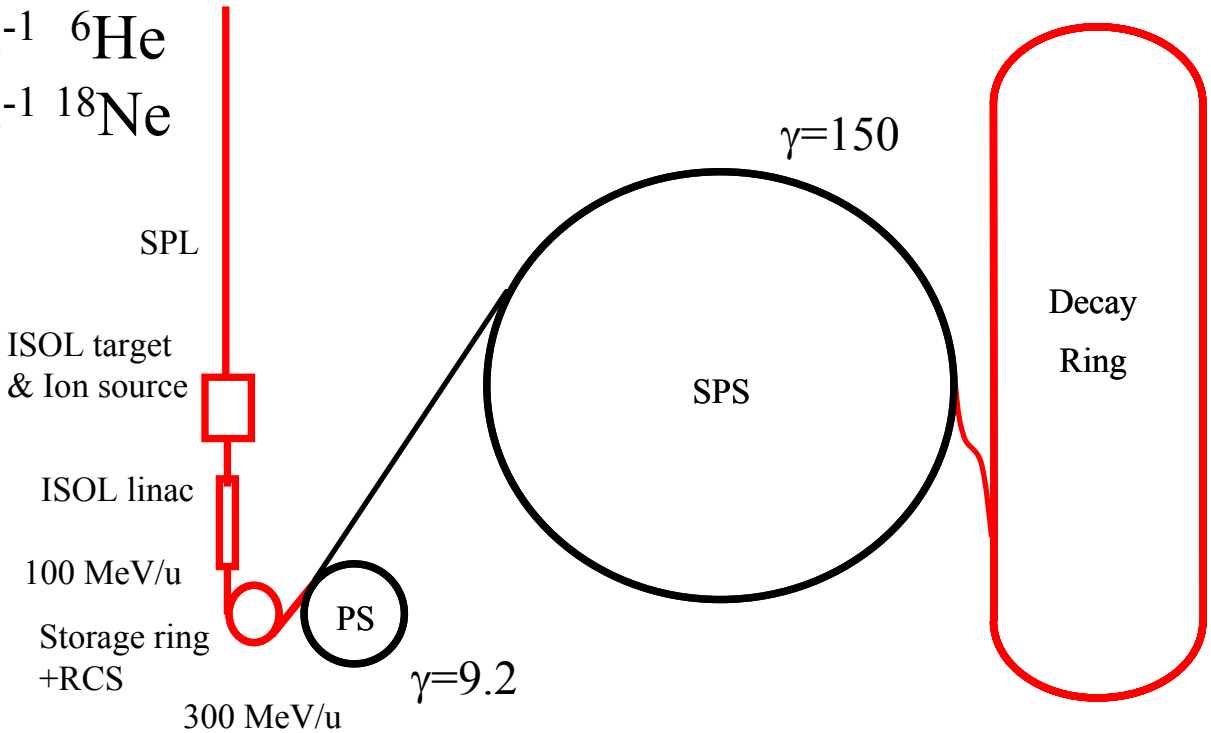
- Take a continuous low energy radioactive ion beam (RIB), accelerate it to high energy and compress it into one or a few short bunches (background suppression).

CERN site study

Ions generated:

2 10^{13} s^{-1} ^{6}He

8 10^{10} s^{-1} ^{18}Ne



Decay ring

Bρ = 1500 Tm

B = 5 T

L_{ss} = 2500 m

Ions stored:

2 10^{14} $^{6}He^{2+}$

9 10^{12} $^{18}Ne^{10+}$

(simultaneously in 4+4 10ns bunches)

[B. Autin et al., Proceedings of Nufact 02, London, 2002, physics/0306106]
+ recent (unpublished) work

Main features of scheme

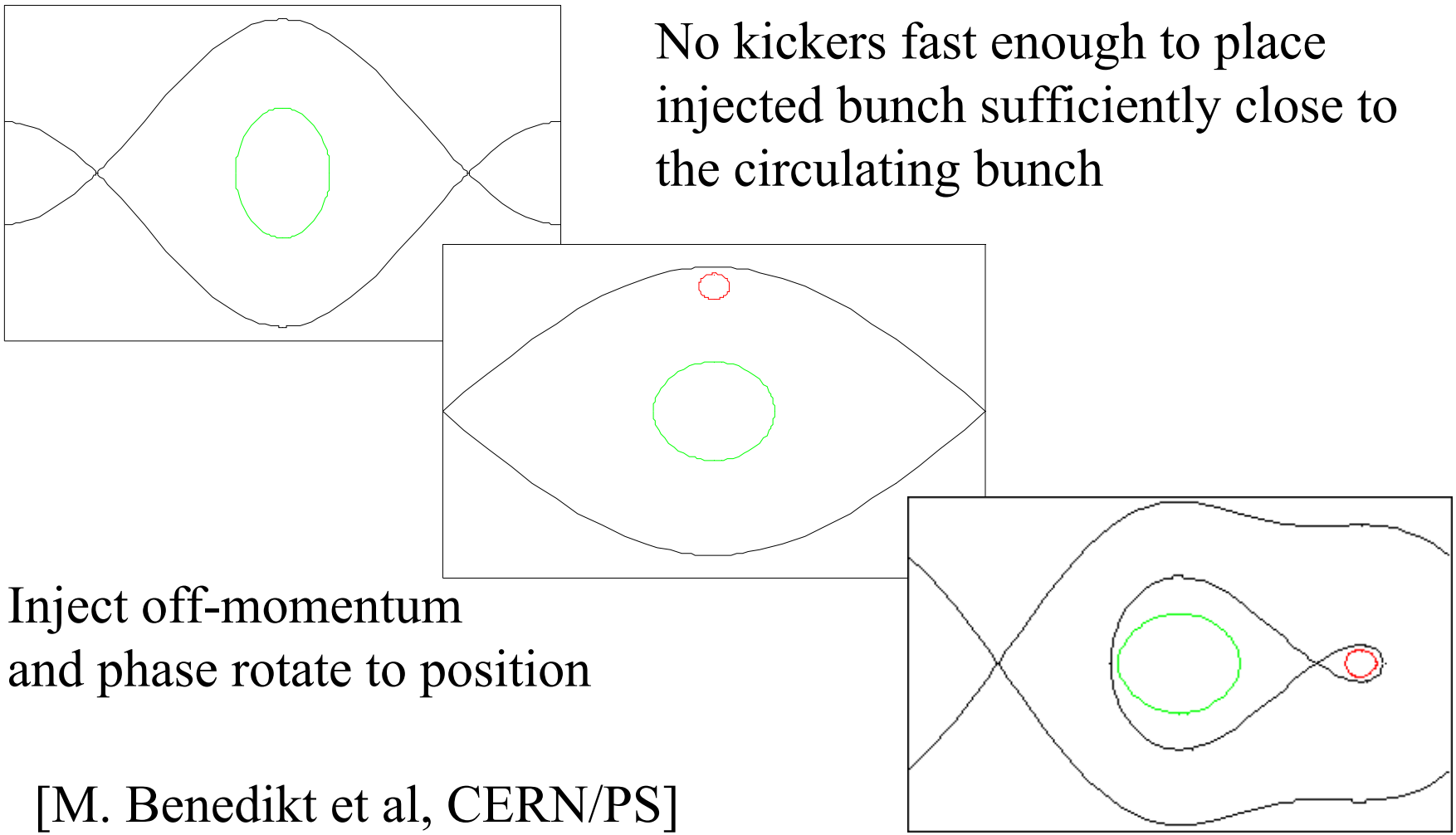
- Production in ISOL target, using high intensity protons
- “Bunching” in duoplasmatron
- Acceleration to 100 MeV/u in linac
- Multiturn injection into RCS, acceleration to 300 MeV/u
- 16 batches to fill PS
- Merging to 8 bunches and controlled blowup
- Transfer to SPS and acceleration
- Transfer to decay ring, two batches of 4.
- Stacking using off-momentum injection, rotation and assymetric bunch merging.

Some identified issues

- Create short pulses from source.
- Stacking w/o cooling in decay ring.
- Radiation and loss power in decay ring (and elsewhere).
- Super-duoplasmatron w gas accumulation?
- Asymmetric bunch merging demonstrated.
- Initial simulations indicates high, but manageable values.

List not exhaustive…

Off-momentum injection

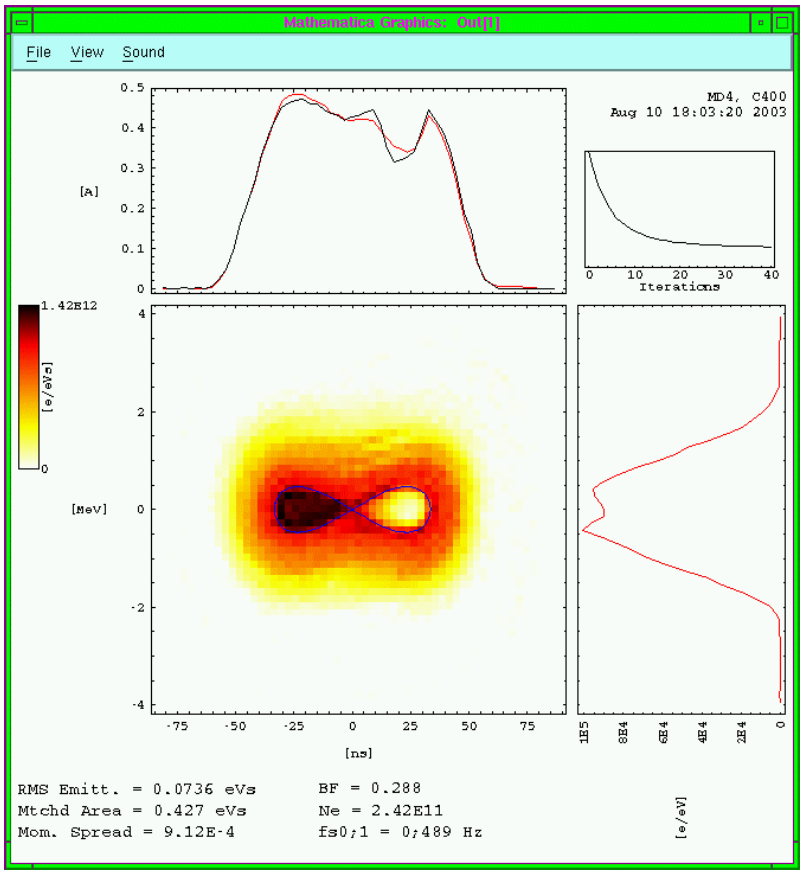


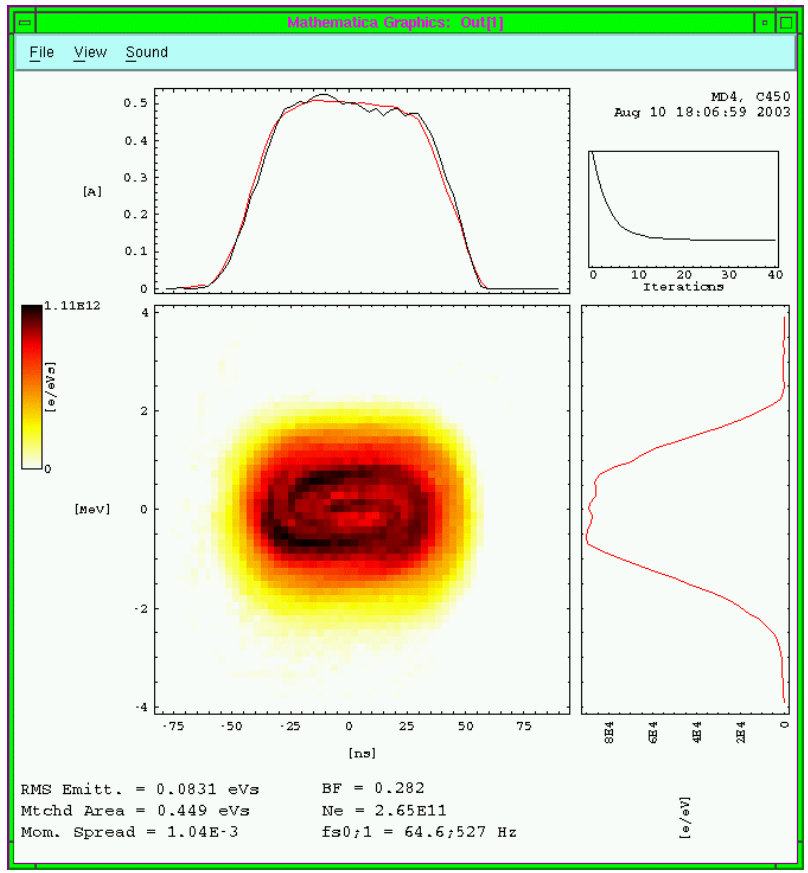
No kickers fast enough to place injected bunch sufficiently close to the circulating bunch

Inject off-momentum
and phase rotate to position

[M. Benedikt et al, CERN/PS]

Asymmetric bunch merging





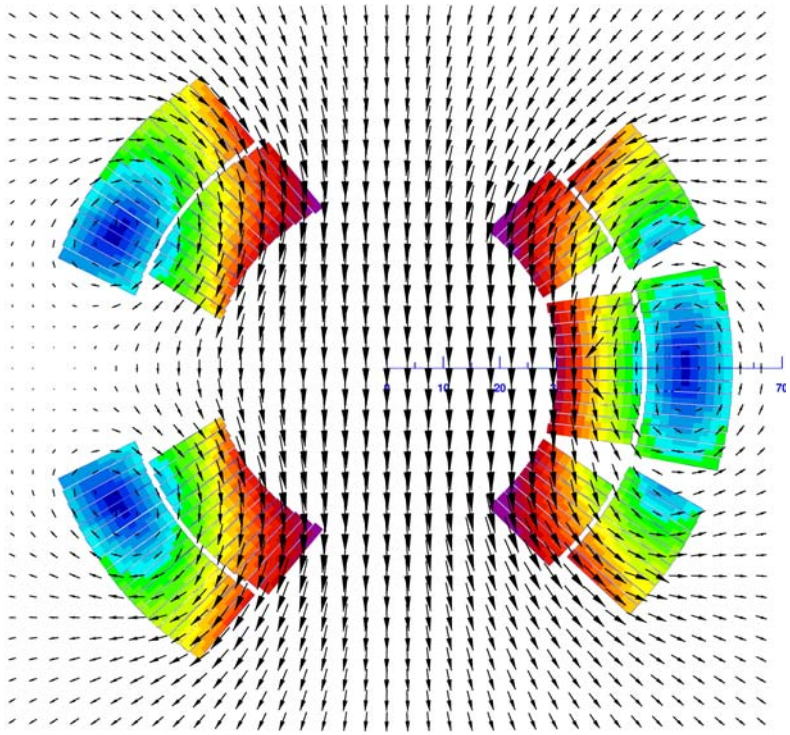
[S. Hancock et al, CERN/PS]

Decay losses

	^{6}He ($T_{1/2}$=0.8 s)	^{18}Ne ($T_{1/2}$=1.67 s)
Accumulation	<47 mW/m	<2.9 mW/m
PS	1.2 W/m	90 mW/m
SPS	0.41 W/m	32 mW/m
Decay ring	23 W/m	1.6 W/m

Superconducting arc magnets

- Can be built with no SC in decay path.
- First indications are that it should work, need more study.



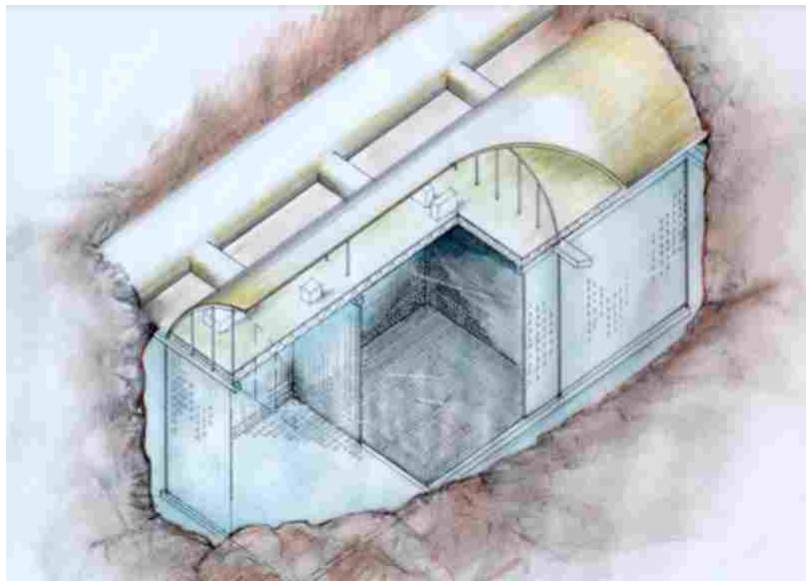
[S. Russenschuck, CERN]

Staging possibilities/physics potential

- Low energy beta-beams
  - Nuclear structure [C. Volpe, hep-ph/0303222]
- Nominal (γ=150) beta-beams
  - Ex: CP violation down to $\theta_{13} \approx 1°$, T & CPT tests [M. Mezzetto, Nufact02 & Nufact03]
- Higher energy beta-beams
  - Under investigation. May be equivalent to muon neutrino factory.

Experiment

- Water cherenkov
  (e.g. UNO).
  - Large mass required
  - No B-field needed
- Multi-use
  - beta-beam
  - super-beam
  - astrophysics
  - proton decay



[image:UNO collaboration]

Beta-beam CP sensitivity

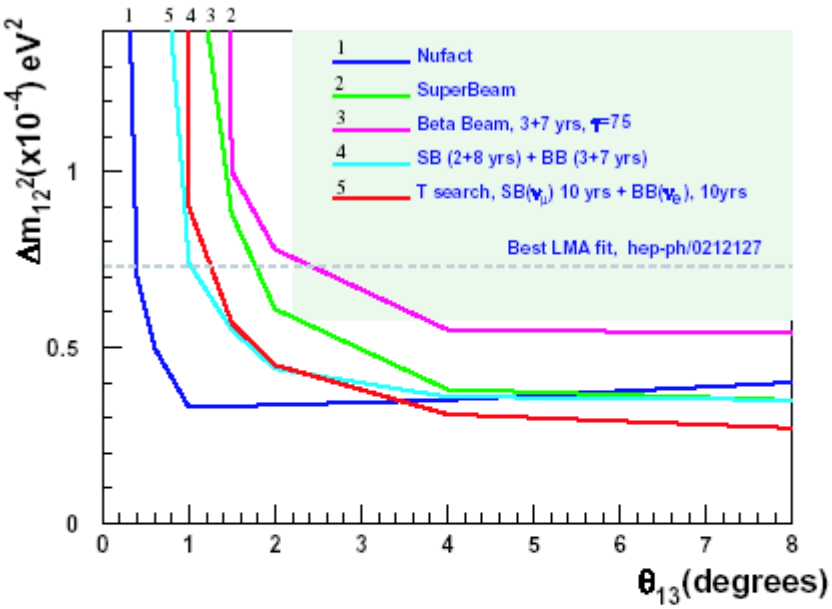


Figure 2. CP sensitivity of the Beta Beam, of the SPL-SuperBeam, and of their combination, see text. Two different time sharing are considered: 3+7 years of $\overline{\nu}_e$, ν_e Beta Beam combined with 2+8 years of ν_μ, $\overline{\nu}_\mu$ Super Beam and 10 years of ν_e Beta Beam with 10 years of ν_μ Super Beam. Sensitivities are compared with a 50 GeV Neutrino Factory producing $2 \cdot 10^{20} \mu$ decays/straight section/year, and two 40 kton detectors at 3000 and 7000 km [8]. The shaded region corresponds to the allowed LMA solution and the θ_{13} sensitivity of JHF.

[M. Mezzetto, hep-ph/0302007]

“Political” status (Europe)

- 2003 Moriond workshop resulted in a letter of intent.
- Applying for EU money to produce a design study.

Letter of Intent: FP6 Design Study for a beta-beam facility

Signatures sorted in alphabetical order on institute and author

Jacques Bouchez*, Olivier Napoly, Jacques Payet,
Saclay, CEA, France

Michael Benedikt, Peter Butler, Roland Garoby, Juan-Jose Gomez Cadenas, Steven Hancock, Pilar Hernandez, Ulli Koester, Mats Lindroos*, Matteo Magistris, Thomas Nilsson, Fredrik Wenander
CERN, Switzerland

Alain Blondel, Simone Gilardoni
Geneva University, Switzerland

Oliver Boine-Frankenheim, Bernhard Franzke, Ralph Hollinger , Markus Steck , Peter Spiller, Helmuth Weick
GSI, Germany

Bernard Laune, *Orsay* , Alex Mueller, *Orsay*, Pascal Sortais, *Grenoble* , Antonio Villari, *GANIL*, Cristina Volpe*, *Orsay*
IN2P3, France

Alberto Facco, *Legnaro*, Mauro Mezzetto*, *Padua*, Vittorio Palladino, *Napoli*, Andrea Pisent, *Legnaro*
INFN, Italy

Thierry Delbar, Guido Ryckewaert
Louvain-la-neuve, Belgium

Marielle Chartier
Liverpool university, UK

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RAL, UK

Dag Reistad
Uppsala university, The Svedberg laboratory, Sweden

Associates:
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Conclusions

- Beta-beams seem feasible, but more work is needed (and underway).
- Strong interest from user community.
- Potential use of a future high intensity proton source at Fermilab.
- If interested, could piggy-back on EU collaboration but would eventually need Fermi site-specific study.
- Would require branch-off into nuclear physics (for radioactive ion production).

http://cern.ch/beta-beam

Fermi site specific questions

- How much of existing/planned accelerator infrastructure could be re-used?
- Limitations of existing accelerators?
- Where to send the beam? Which experiment?
- Environmental impact (radiation), and geographical restrictions?
- (Incremental) cost?