The Beta-beam

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

Mats Lindroos
on behalf of
The beta-beam study group

Collaborators

- The beta-beam study group:
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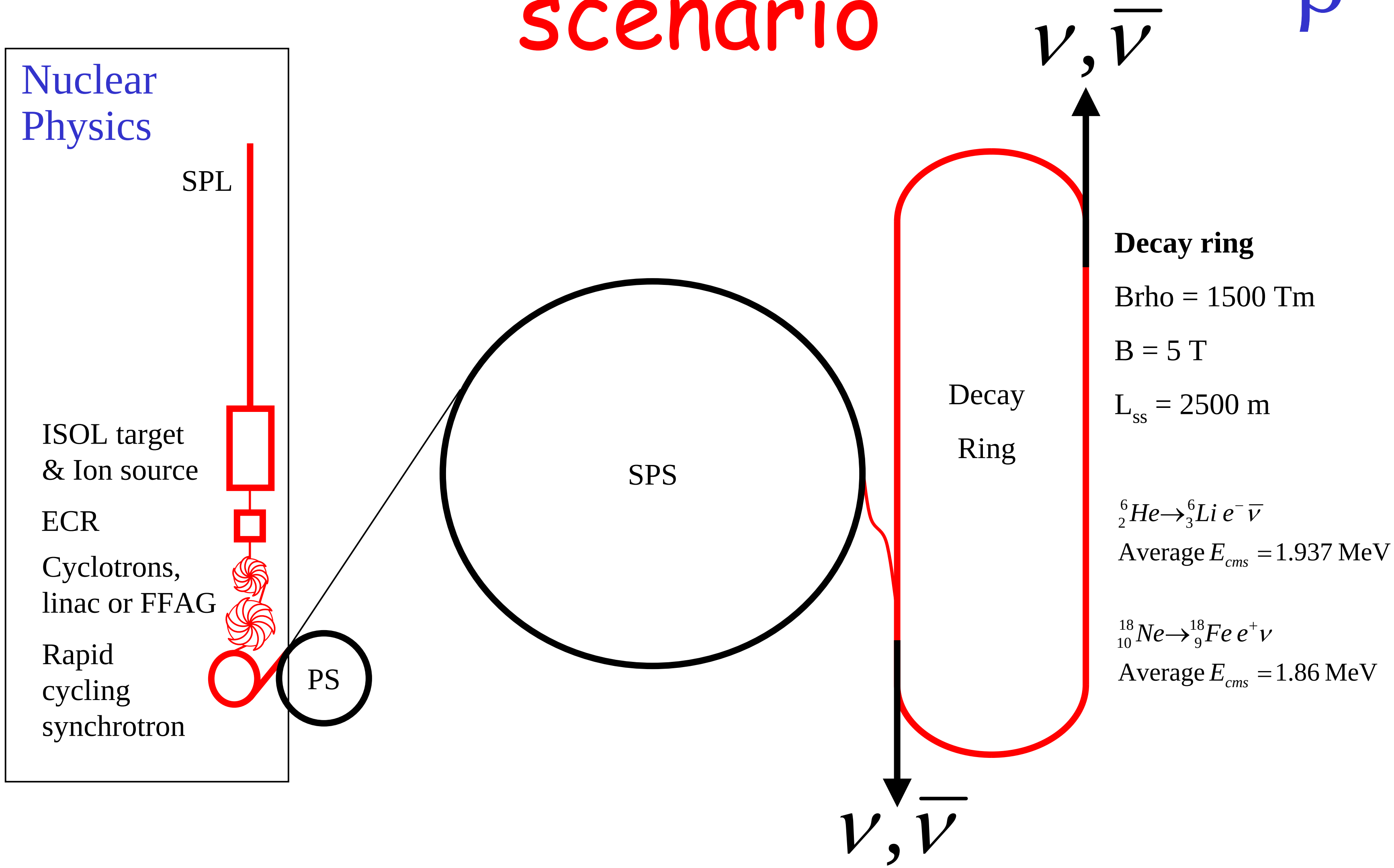
  - **IFIC, Valencia:** Jordi Burguet, Juan-Jose Gomez-Cadenas, Pilar Hernandez, Jose Bernabeu
  - **IN2P3, France:** Bernard Laune, Orsay, Paris Alex Mueller, Orsay, Paris Pascal Sortais, Grenoble Antonio Villari, GANIL, CAEN Cristina Volpe, Orsay, Paris
  - **INFN, Italy:** Alberto Facco, Legnaro Mauro Mezzetto, Padua Vittorio Palladino, Napoli Andrea Pisent, Legnaro Piero Zucchelli, Sezione di Ferrara
  - **Louvain-la-neuve, Belgium:** Thierry Delbar Guido Ryckewaert
  - **UK:** Marielle Chartier, Liverpool university Chris Prior, RAL and Oxford university
  - **Uppsala university, The Svedberg laboratory, Sweden:** Dag Reistad
  - **Associate:** Rick Baartman, TRIUMF, Vancouver, Canada Andreas Jansson, Fermi lab, USA, Mike Zisman, LBL, USA

The beta-beam

- Idea by Piero Zucchelli
  - *A novel concept for a neutrino factory: the beta-beam*, Phys. Let. B, 532 (2002) 166-172
- The CERN base line scenario
  - Avoid anything that requires a "technology jump" which would cost time and money (and be risky)
  - Make use of a maximum of the existing infrastructure
  - If possible find an "existing" detector site

CERN: β-beam baseline scenario



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Target values for the decay ring

$^{6}Helium^{2+}$

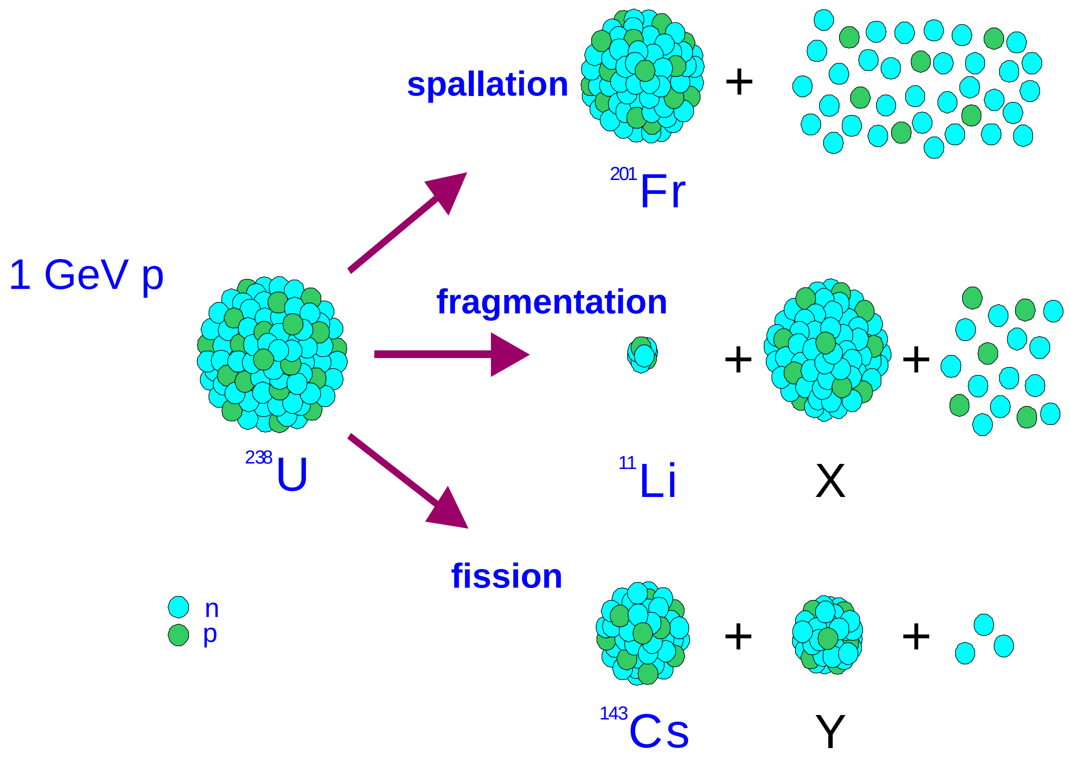
- In Decay ring: 1.0×10^{14} ions
- Energy: 139 GeV/u
- Rel. gamma: 150
- Rigidity: 1500 Tm

$^{18}Neon^{10+}$ (single target)

- In decay ring: 4.5×10^{12} ions
- Energy: 55 GeV/u
- Rel. gamma: 60
- Rigidity: 335 Tm

- The neutrino beam at the experiment should have the "time stamp" of the circulating beam in the decay ring.
- The beam has to be concentrated to as few and as short bunches as possible to maximize the number of ions/nanosecond. (background suppression), aim for a duty factor of 10^{-4}

ISOL production



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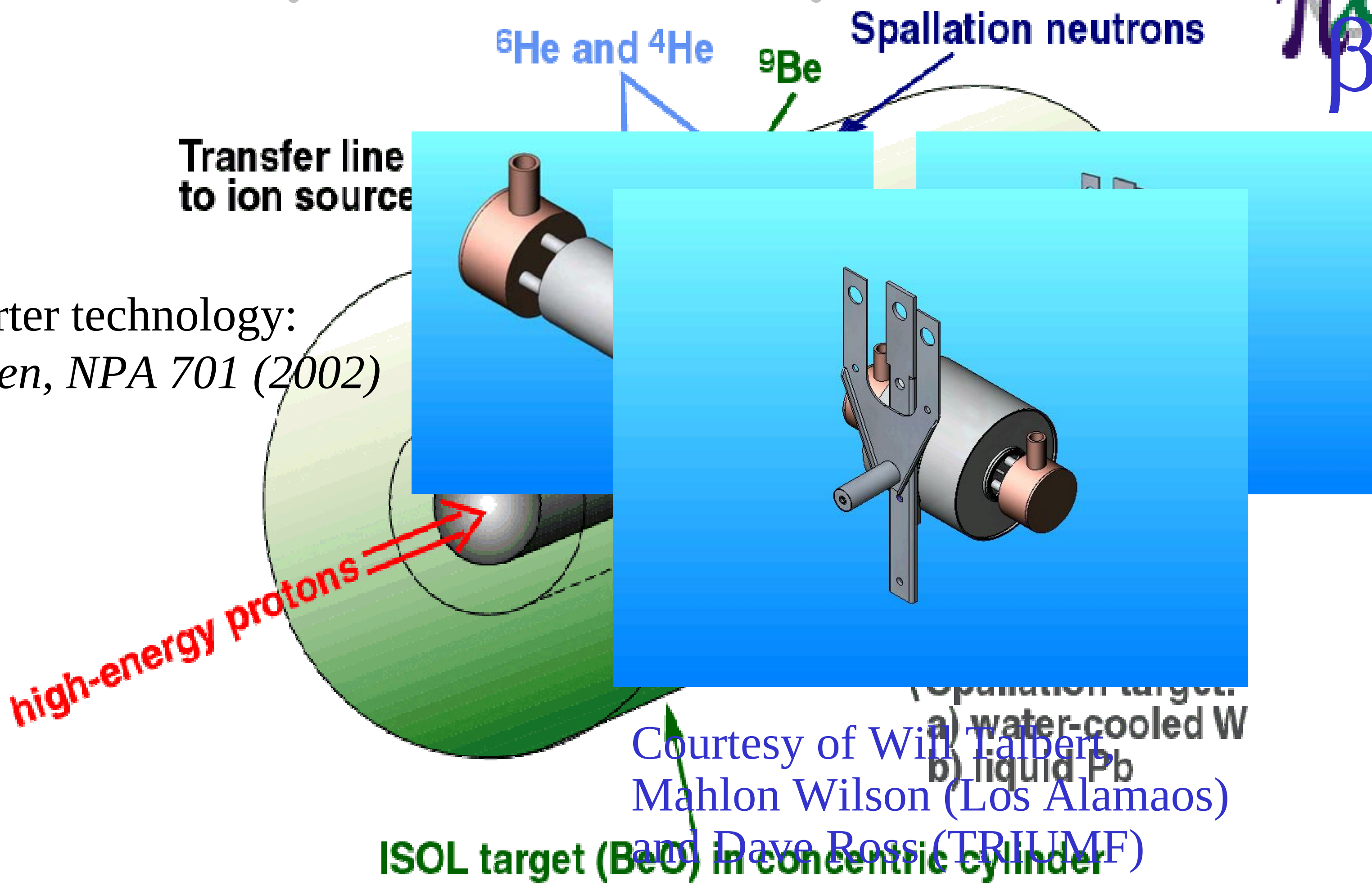
^{6}He production by ^{9}Be(n,α)

Converter technology:
(J. Nolen, NPA 701 (2002) 312c)



Courtesy of Will Talbert, Mahlon Wilson (Los Alamaos) and Dave Ross (TRIUMF)

Layout very similar to planned EURISOL converter target aiming for 10^{15} fissions per s.

Production of β^+ emitters

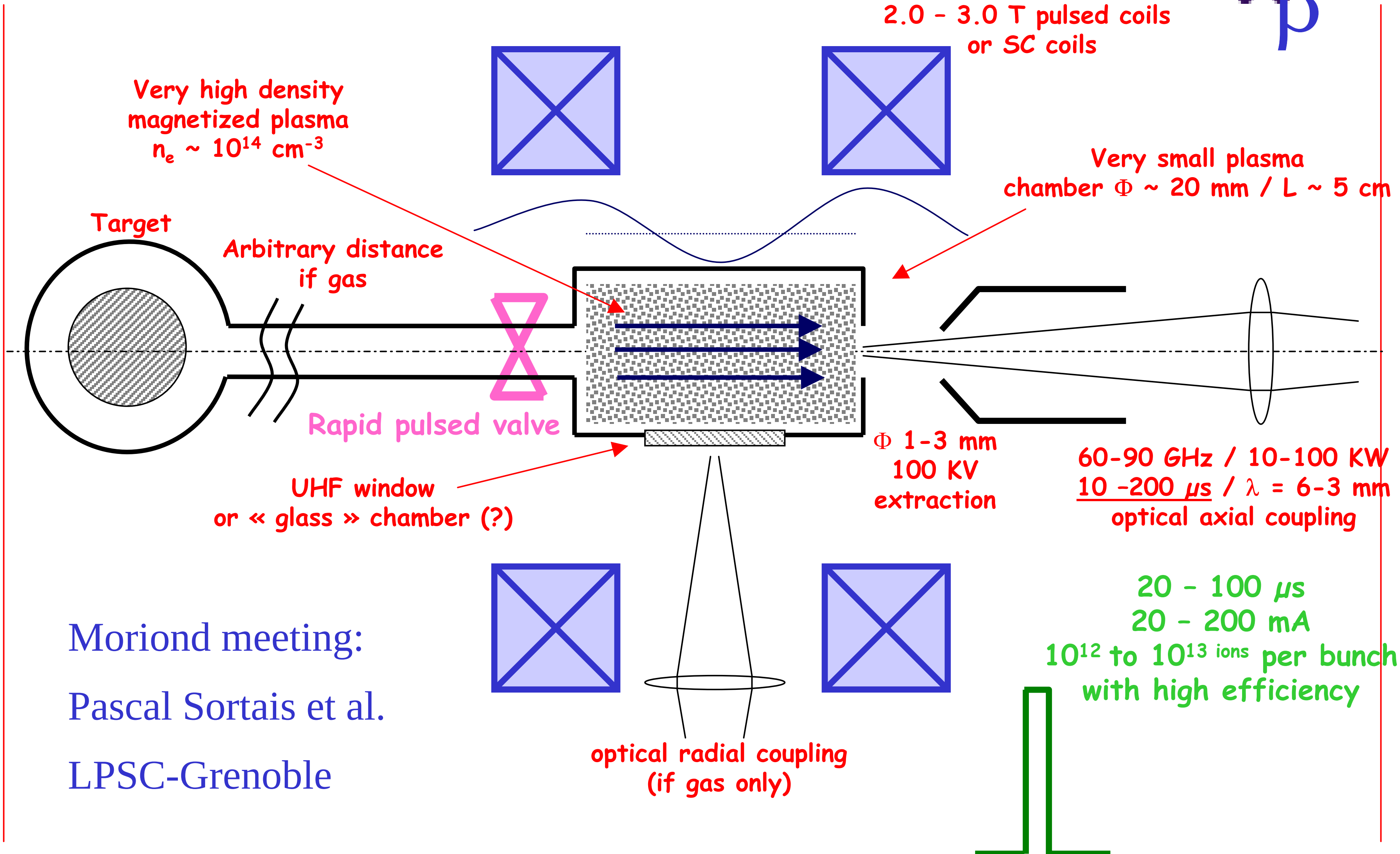
Scenario 1

- **Spallation of close-by target nuclides:**
  $^{18,19}Ne$ from MgO and $^{34,35}Ar$ in CaO
  - **Production rate for ^{18}Ne is $1x10^{12}$ s^{-1} (with 2.2 GeV 100 μA proton beam, cross-sections of some mb and a 1 m long oxide target of 10% theoretical density)**
  - **^{19}Ne can be produced with one order of magnitude higher intensity but the half life is 17 seconds!**

Scenario 2

- **alternatively use (α,n) and (^3He,n) reactions:**
  $^{12}C(^{3,4}He,n)^{14,15}O$, $^{16}O(^{3,4}He,n)^{18,19}Ne$, $^{32}S(^{3,4}He,n)^{34,35}Ar$
  - **Intense $^{3,4}He$ beams of 10-100 mA 50 MeV are required**

60-90 GHz « ECR Duoplasmatron » for pre-bunching of gaseous RIB



Moriond meeting:

Pascal Sortais et al.

LPSC-Grenoble

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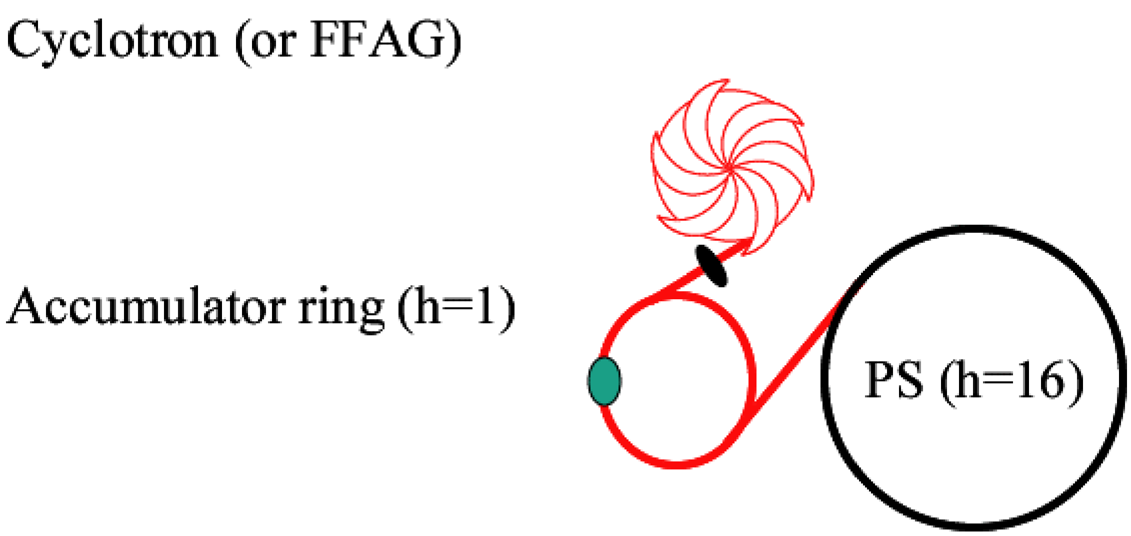
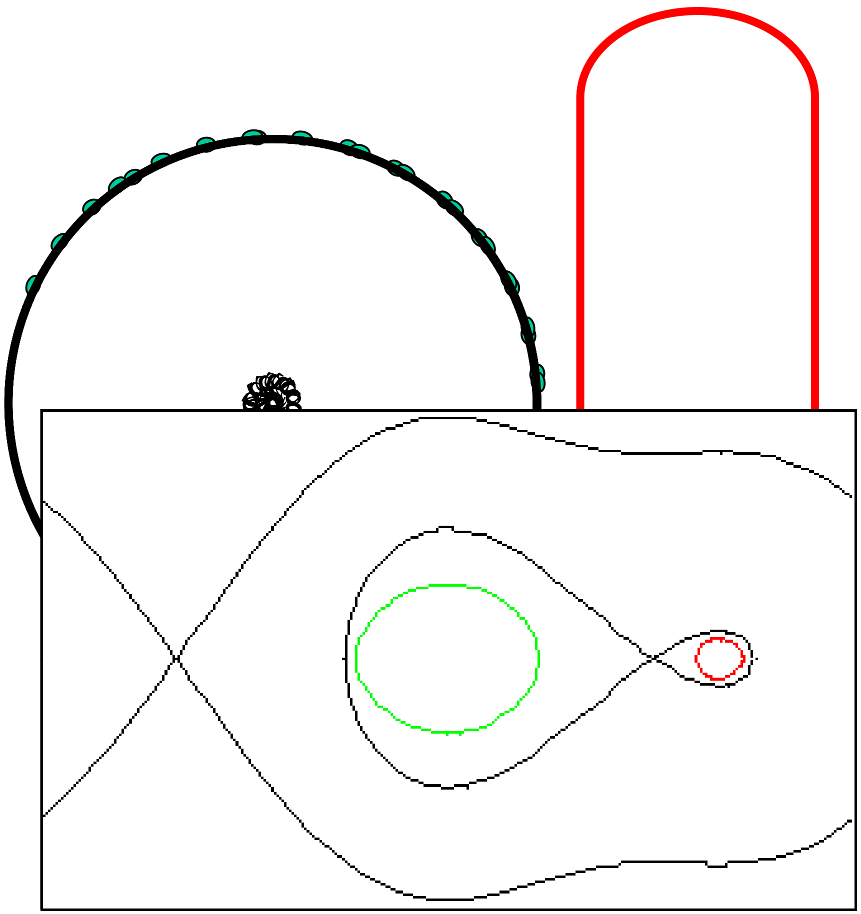
Overview: Accumulation



- Sequential filling of 16 buckets in the PS from the storage ring

Stacking in the Decay ring

- Ejection to matched dispersion trajectory
- Asymmetric bunch merging



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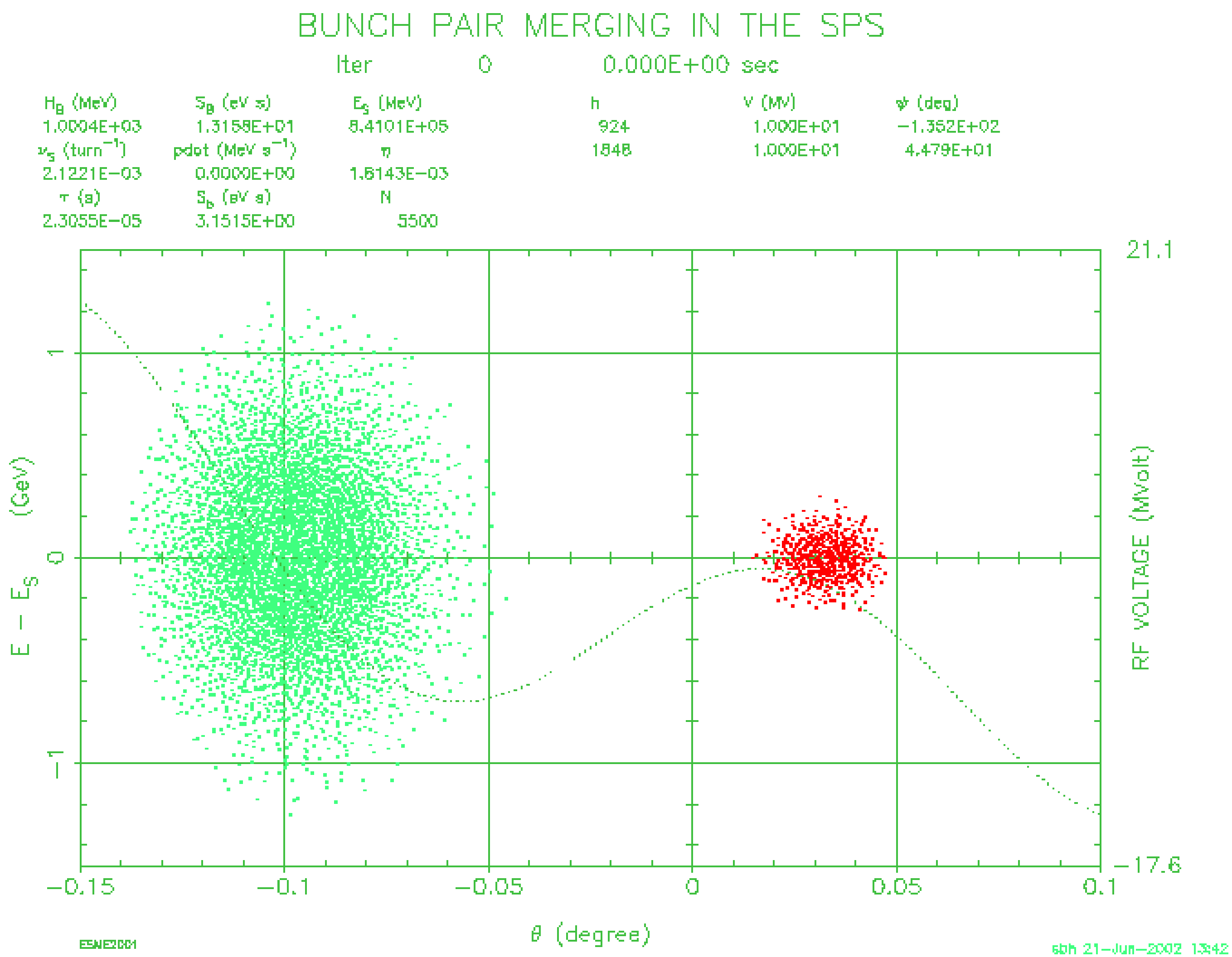
Asymmetric bunch merging



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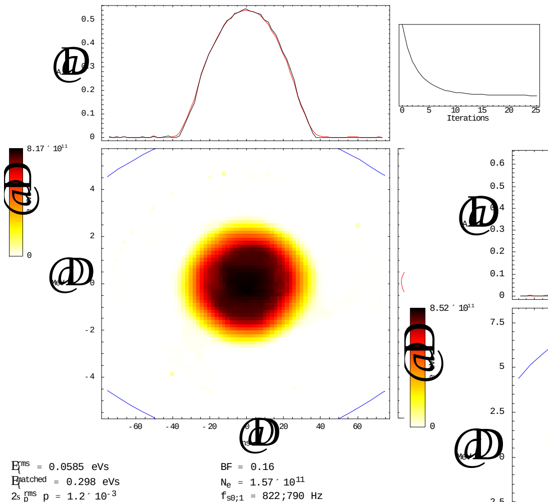
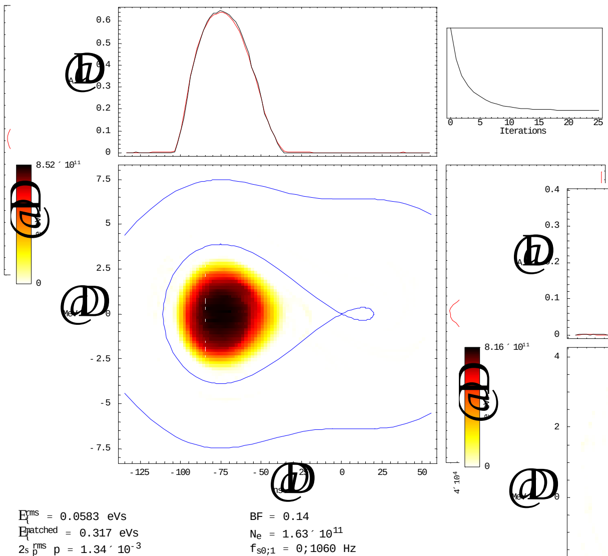
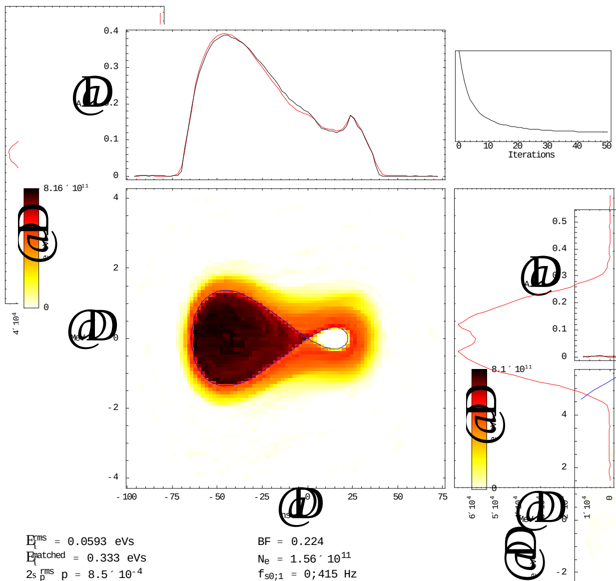
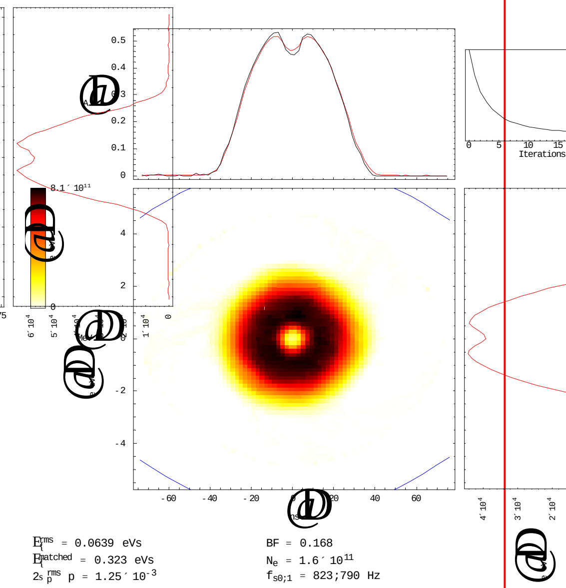
Asymmetric bunch merging









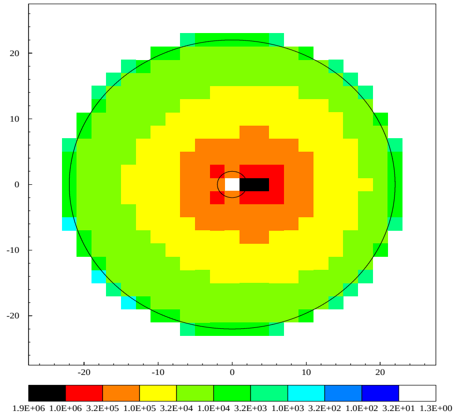
(S. Hancock, M. Benedikt and J,-L.Vallet, *A proof of principle of asymmteric bunch pair merging*, AB-note-2003-080 MD)

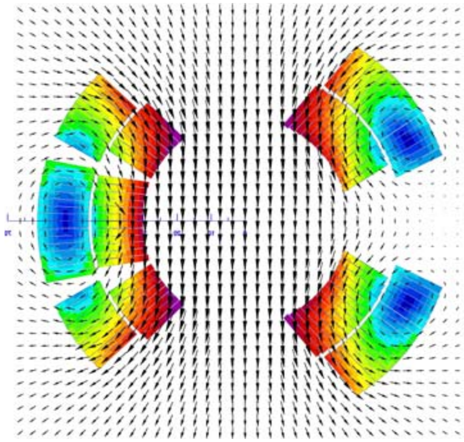
Decay losses

- Losses during acceleration are being studied:
  - Full FLUKA simulations in progress for all stages (M. Magistris and M. Silari, *Parameters of radiological interest for a beta-beam decay ring*, TIS-2003-017-RP-TN)
  - Preliminary results:
    - Can be managed in low energy part
    - PS will be heavily activated
      - New fast cycling PS?
    - SPS OK!
    - Full FLUKA simulations of decay ring losses:
      - Tritium and Sodium production surrounding rock well below national limits
      - Reasonable requirements of concreting of tunnel walls to enable decommissioning of the tunnel and fixation of Tritium and Sodium

SC magnets

- Dipoles can be built with no coils in the path of the decaying particles to minimize peak power density in superconductor
  - The losses have been simulated and one possible dipole design has been proposed

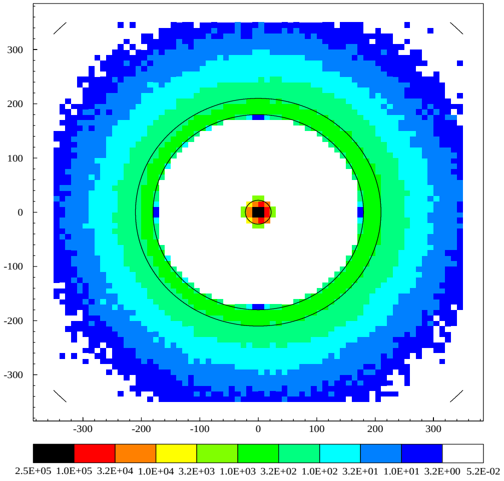




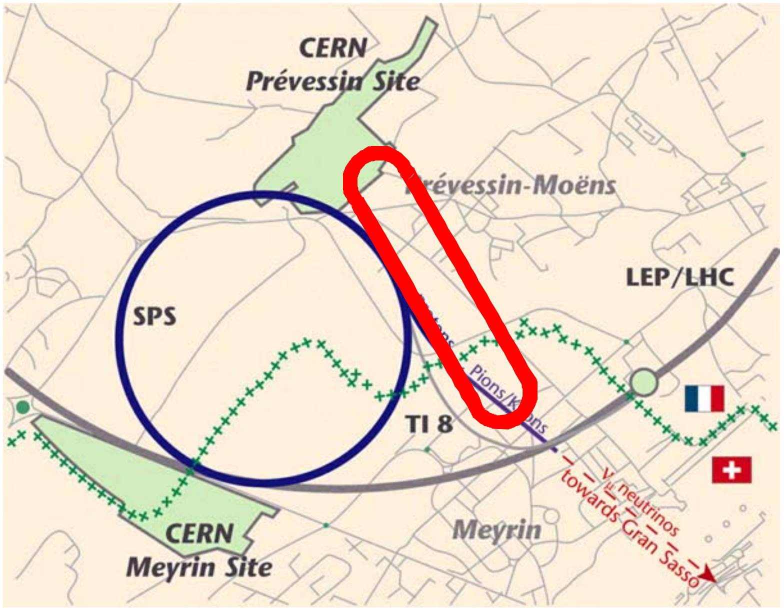
S. Russenschuck, CERN

Tunnels and Magnets

- Civil engineering costs: Estimate of 400 MCHF for 1.3% incline (13.9 mrad)
  - Ringlenth: 6850 m, Radius=300 m, Straight sections=2500 m
- Magnet cost: First estimate at 100 MCHF



FLUKA simulated losses in surrounding rock (no public health implications)



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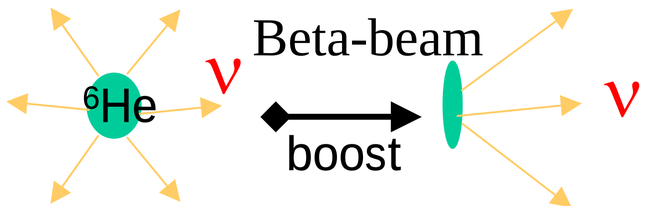
Intensities

Stage	^{6}He	^{18}Ne (single target)
From ECR source:	2.0×10^{13} ions per second	0.8×10^{11} ions per second
Storage ring:	1.0×10^{12} ions per bunch	4.1×10^{10} ions per bunch
Fast cycling synch:	1.0×10^{12} ion per bunch	4.1×10^{10} ion per bunch
PS after acceleration:	1.0×10^{13} ions per batch	5.2×10^{11} ions per batch
SPS after acceleration:	0.9×10^{13} ions per batch	4.9×10^{11} ions per batch
Decay ring:	2.0×10^{14} ions in four 10 ns long bunch	9.1×10^{12} ions in four 10 ns long bunch

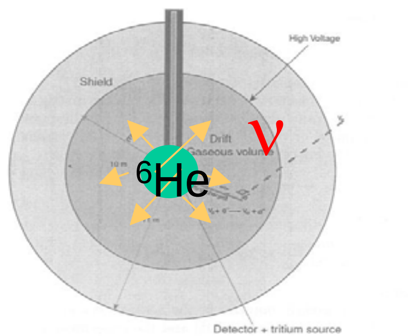
Only β-decay losses accounted for, add efficiency losses (50%)

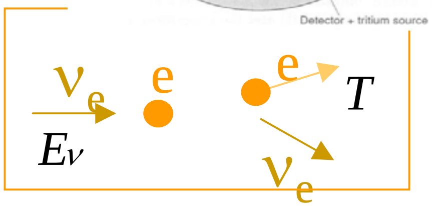
Low energy beta-beam

- The proposal
  - To exploit the beta-beam concept to produce intense and pure low-energy neutrino beams (C. Volpe, hep-ph/0303222, To appear in Journ. Phys. G. 30(2004)L1)
- Physics potential
  - Neutrino-nucleus interaction studies for particle, nuclear physics, astrophysics (nucleosynthesis)
  - Neutrino properties, like n magnetic moment



$^6He \rightarrow {}^6Li + e + \bar{\nu}_e$ Q_β=4. MeV



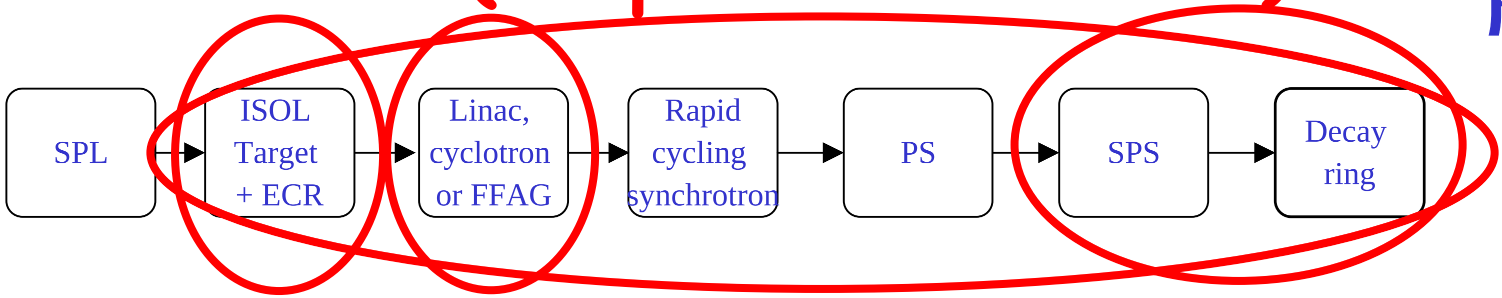


Neutrino-nucleus Interaction Rates

at a Low-energy Beta-beam Facility

	Intensities	γ	Detectors
GANIL	10^{12} ν/s A. Villari (GANIL)	1	4π
GSI	10^{9} ν/s H. Weick (GSI)	1-10	4π and Close detector
CERN (EURISOL)	10^{13} ν/s Autin *et al*, J.Phys. (2003).	1-100	4π and Close detector

R&D (improvements)



- Production of RIB (intensity)
  - Simulations (GEANT, FLUKA)
  - Target design, only 100 kW primary proton beam in present design
- Acceleration (cost)
  - FFAG versa linac/storage ring/RCS
- Tracking studies (intensity)
  - Loss management
- Superconducting dipoles (γ of neutrinos)
  - Pulsed for new PS/SPS (GSI FAIR)
  - High field dipoles for decay ring to reduce arc length
  - Radiation hardness (Super FRS)

Design Study

USERS
Frejus
Gran Sasso
High Gamma
Astro-Physics
Nuclear Physics
(γ, intensity and duty factor)

EURISOL
Beta-beam Coordination
Beta-beam parameter group
Above 100 MeV/u
Targets
60 GHz ECR
Low energy beta-beam
And many more…

OTHER LABS
TRIUMF
FFAG
Tracking
Collimators
US study
Neutrino Factory DS

Conceptual Design # with price ### M€

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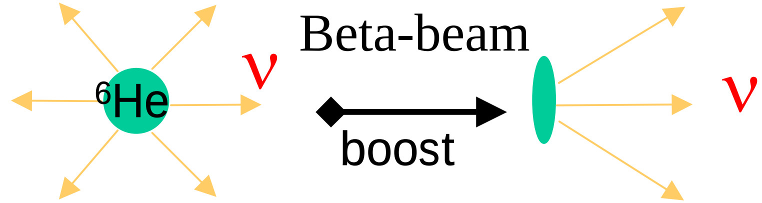

- A boost of proton intensities
    - A boost for radioactive nuclear beams
        - A boost for neutrino physics
- And tomorrow…

“The chances of a neutrino actually hitting something as it travels through all this emptiness are roughly comparable to that of dropping a ball bearing from a cruising 747* and hitting, say an egg sandwich”, Douglas Adams, Mostly Harmless, Chapter 3

*) European A380, Prototype will fly in 2005