Radioactive-Ions Production Ring for Beta-Beams

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Beta Beams, EUROnu WP4

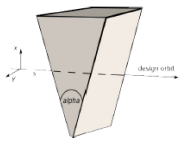
The idea

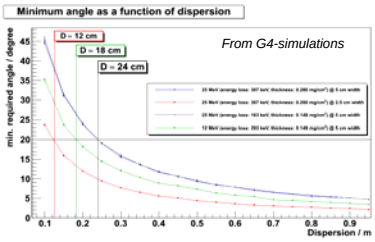
- *Beam cooling with ionization losses, C.Rubbia et al., NIM A 568 (2006) 475-487*
- Enhance β-emitters production (~10^{14}/s) by multi passages through a thin target
- $^7Li + D \rightarrow {}^8Li + p$ $^6Li + {}^3He \rightarrow {}^8B + n$
- Compact ring and internal target
- Inverse kinematic: 25MeV Li beam and D or ^{3}He supersonic gas-jet target
- Ionization cooling:
  - Energy losses in the target
  - Only longitudinal component recovered in RF cavities
    → Transverse emittance shrinks
  - Cooling in 6D → wedged shaped target & dispersion

→ see also ERIT, proton FFAG w. internal Be target for neutron production
Y.Mori, NIM A 562 (2006) 591 (but FFAGs do not require dp/p cooling)

Wedge shaped target in dispersive region

- Cooling in longitudinal plane
- Coupling x-z via Dispersion



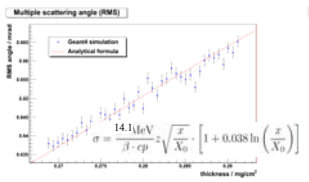


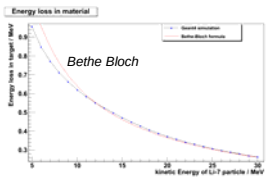
- 25 MeV ^{7}Li beam
- Target:
  - width @ closed orbit = 5cm
  - thickness = 0.289 mg/cm^2
- If angle = 20° → D_x > 24 cm

D_x set to ~ 50 cm

Geant4 Simulations

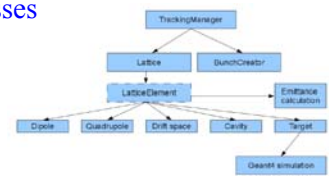
- Gas-jet target modeled as solid block
- Production → G4 hadronic model not valid at low energies of interest
- EM interactions → Ok



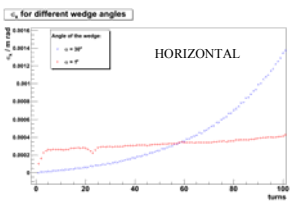


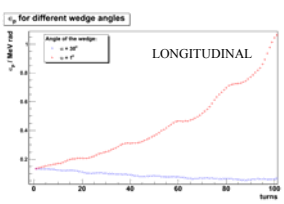
Tracking w. G4 and C++ classes

- Developed classes in C++ for 6D tracking
- RF cavity modeling:
  $\Delta E_{RF} = qV \sin(\phi_s + 2\pi f_0 \Delta t)$
  $\Delta u' = -u'(\Delta p/p)$, u=x,y
  V=300 keV
  ϕ_s=0.34



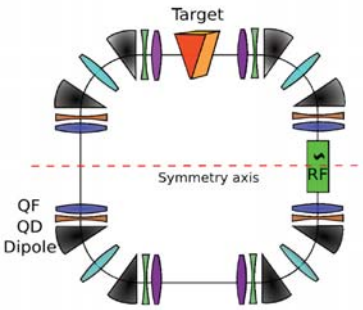
- The reference ^{7}Li particle gains 300 keV/turn (=average value lost @ target)
- PRELIMINARY: heating/cooling in the horiz/longitud according to wedge angle

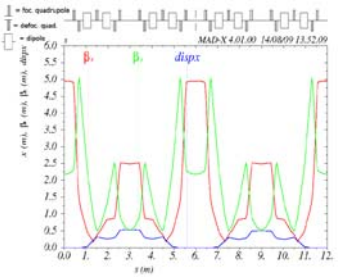


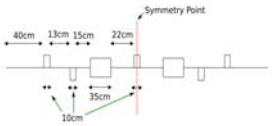


The proposed lattice

- 25 MeV ^{7}Li (βρ ~0.6)
- C = 12m
- 5 quadrupole families
- normal-conducting magnets
- 2-fold mirror symmetry
  - RF cavity → in region D_x=0
  - Target → D_x~50cm
- Q_x= 2.56
- Q_y= 1.59
- γ_{tr}= 3.59

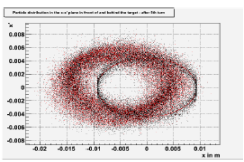






Tracking w. SixTrack

- Target implemented in SixTrack (*LHC-Collimation Version*):
  - Collimators routine modified to include our new type of "beam obstacle"
- Kick in transverse direction (Multiple Coulomb Scattering) & energy losses
  - ∀particle randomly generated according to rms & mean from Moliere & Bethe-Bloch formulas



VERY PRELIMINARY!!!
- Heating in transverse plane
- BUT RF not optimized!!!

Summary, open issues & future plans

- Preliminary studies, mainly on the ^{7}Li beam
  - Design of a production-ring lattice, quite compact & flexible.
  - Tracking tools (SixTrack & C++ classes) in place and preliminary results
  - Interaction target-beam w. Geant4
    - Production → G4 not adequate, use Fluka, Mars, or implement new-physics in G4
    - Multiple-Coulomb scattering and energy losses → well approx w. analytical formula
- Next steps:
  - Six-Track simulations ↔ lattice & RF optimization
  - Cooling in 6D → is it necessary coupling x-y, as proposed by [D.Neuffer]?
  - Interaction target-beam and production of radioactive isotopes
  - Requirements in terms of Li-beam intensity, emittances, longitudinal profile, max Δp/p allowed, rep. rate, ...
- Many technological issues:
  - Collection device: ring-shaped thin Tantalum foil + diffusion/effusion (*cfr. tecniques @ ISOLDE*) to ECR source → very close to the circulationg beam
  - Supersonic gas-jet target technology
  - Injection
  - Vacuum

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