Collimation and absorption in the decay ring

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Contents

Collimation:

- Beam halo
  - Similar to stable ion collimation
- Momentum collimation
  - Longitudinal phase space increase after merging
- Decay products (beta-beam principle)
  - in arcs (absorption)
  - in straight section (extraction)

- Normal operation
  - Protect beam elements (especially SC magnets)
- Irregular operation (failure of active elements)
  - Beam dump

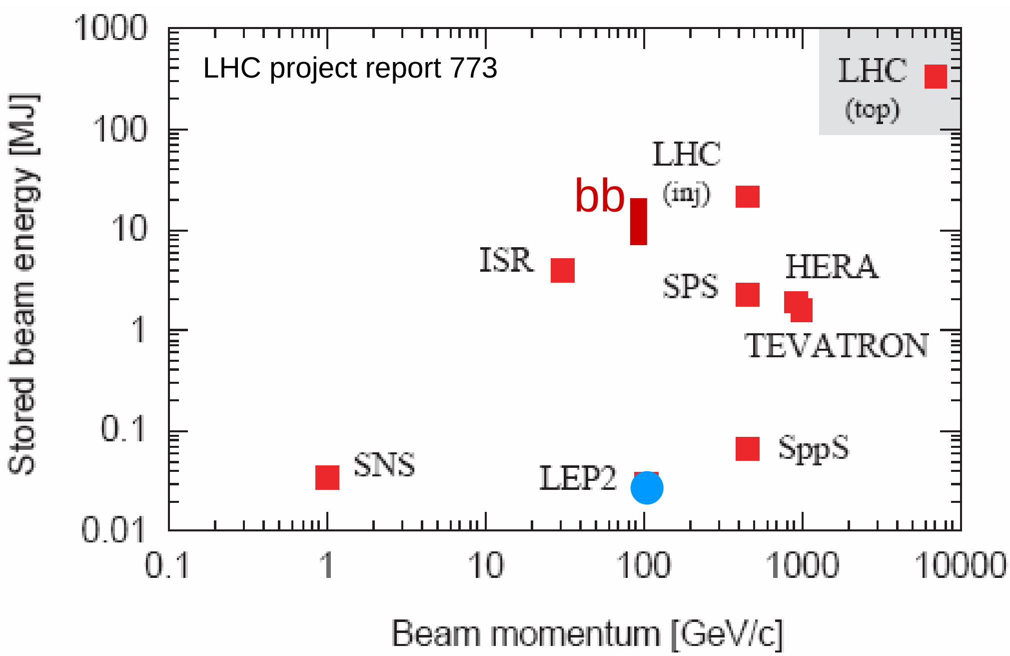
Beam intensities (1)

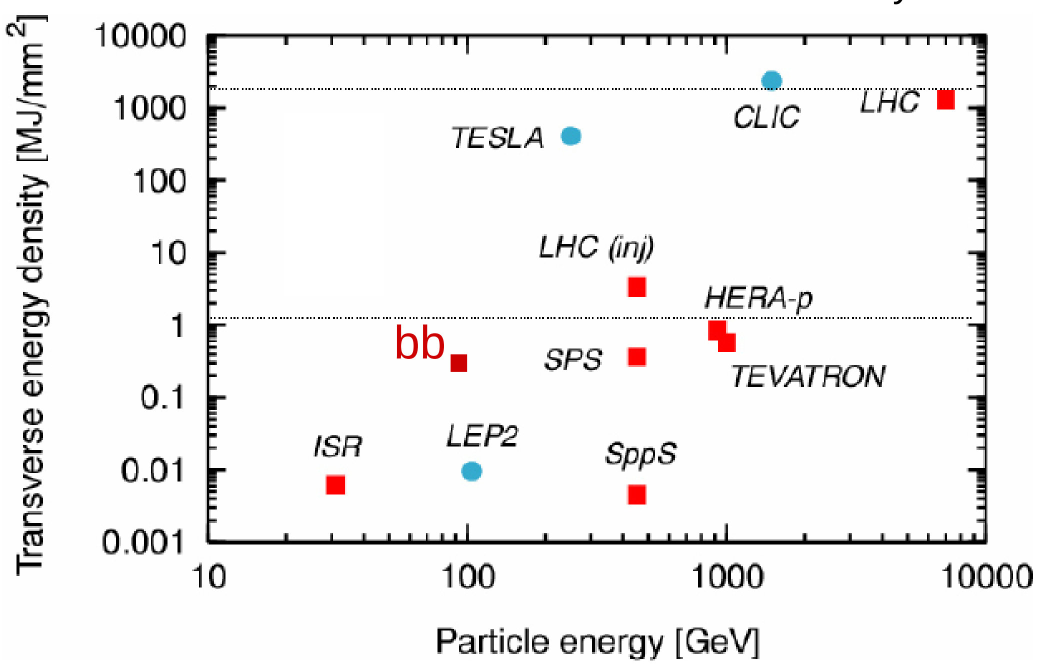
- Beta-beam scenario compared with LHC proton/lead ion operation

	Beta-beam		LHC	
	He^6	Ne^{18}	proton	Lead ion
Relativistic γ	100	100	7461	2964
T/nucleon (GeV)	93	93	7000	2759
T/ion (GeV)	555	1660	7000	$574\ 10^3$
Injected ions	$9\ 10^{12}$	$4.3\ 10^{12}$	$3.2\ 10^{14}$	$4\ 10^{10}$
τ_{cycle} (s)	6	3.6	hours	hours
Number of stored ions	$9.71\ 10^{13}$	$7.4\ 10^{13}$	$3.2\ 10^{14}$	$4\ 10^{10}$
Stored beam energy (MJ)	8.8	19.7	362	3.8

Beam intensities (2)

- Stored energy
  - LHC refers to proton operation.
- Transverse density: $\rho = E_{stored}/(2*Pi*\sigma_x*\sigma_y)$

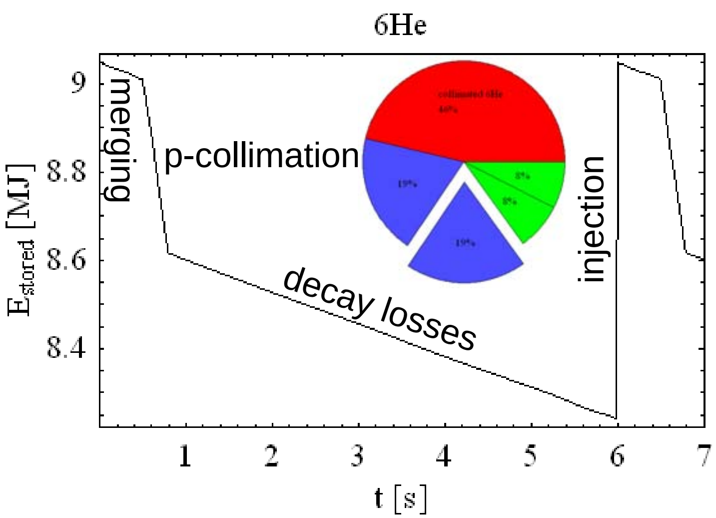


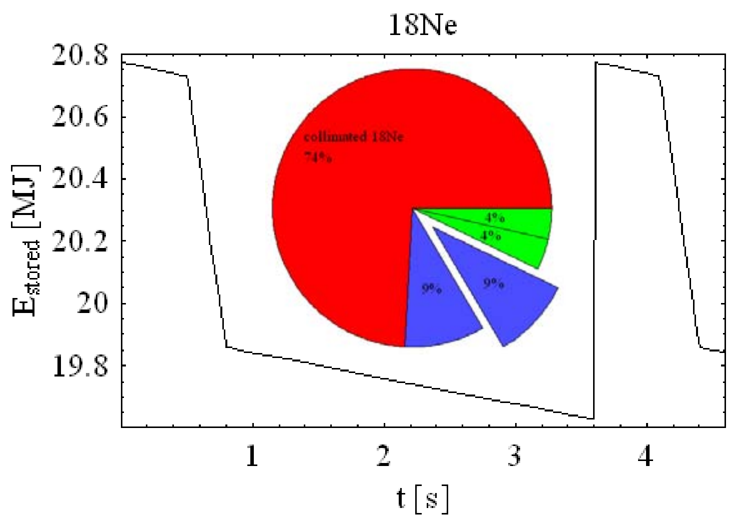


- Beta-beam operates at reasonable stored energy/energy density
  - "Stored energy" is most relevant for irregular operation.

Particle turnover

- 810 kJ respect. 1150 kJ beam energy/cycle injected → ejected
  - All ions have to be removed again
  - either as parent or daughter ion





Energy deposition on collimators

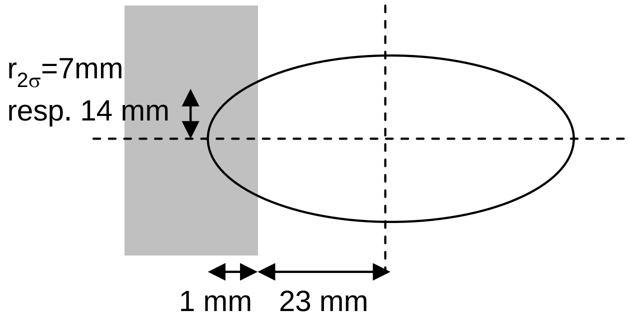
- Beta-beam:

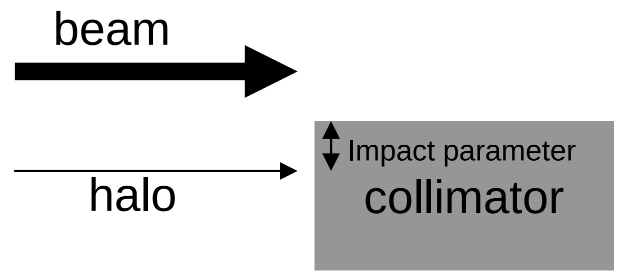
  Decay losses are distributed in time → 11 W/m energy loss

  - Decay deposition in **arcs**: protect SC dipoles from quench caused by deposition accumulated after drift (quench limit 10W/m)
  - Decays accumulated along **straight section**: 300 or 400 kJ dumped per cycle (50 or 120 kW average) via extraction system at end of straight section
  - Momentum collimation at/after merging process:
    - Cycle average: 62 or 230 kW (6 resp 3.6 s)
    - Process average: 1.2 or 2.8 MW (0.3 s, continuos collimation during bunch compression)
- Power deposition on LHC collimators
  - Typical (τ_{beam} = 10 hours): 10 kW average
  - Peak specifications: 100 kW over seconds or 500 kW peak

Momentum collimation

- Beam size on the collimator front face
  - 0.5 mm x 7 mm resp. 1 mm x 14 mm



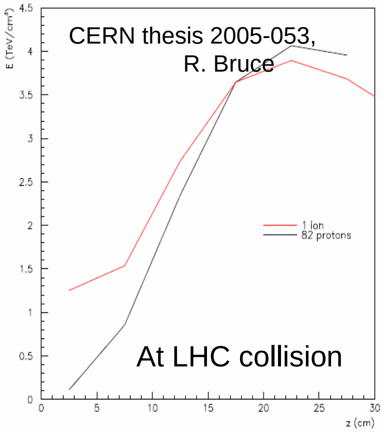


- Single- or multi stage collimation system
  - Increased impact parameter allows to think about a single stage system

- **Minimum collimation time** given by revolution time in synchrotron phase space: lasts about ~1000 turns in decay ring (=23 ms)
  - Requires kicker system
  - Increased impact parameter increases power deposition up to several Megawatt peak

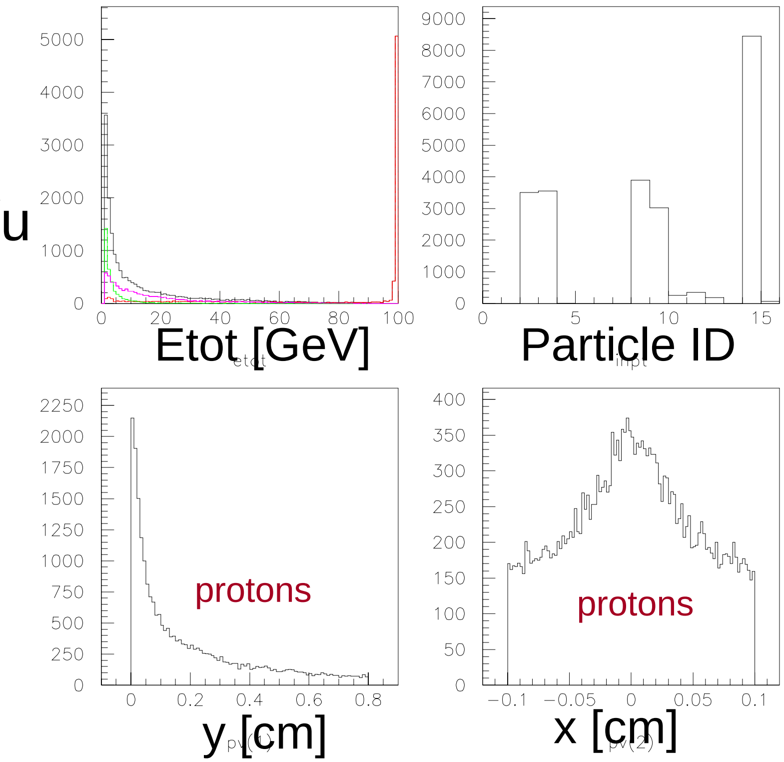
- **Longer times** only allowed by continuous collimation during process of merging and/or bunch compression (minimum time required about 300 ms, can be extended up to cycle length)

Simplified deposition simulation



Collimator: carbon target, l=1m, width=1 mm, height infinite

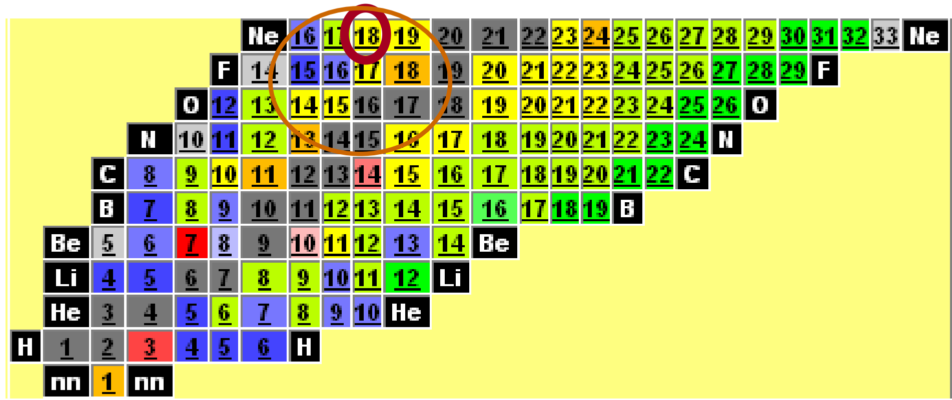
- 10^5 protons on target, 100 GeV/u
- 1.5 10^5 particles out
  - 2.3 10^4 charged
    - 7 10^3 leptons
    - 7 10^3 pions
    - 8 10^3 protons typically at 100 GeV/u
      - ~10% percent of initial beam power



- Justifies the effort on maximizing the impact parameter for collimators
- Geant3 simulation

Fragmentation

^{18}Ne fragmentation products:



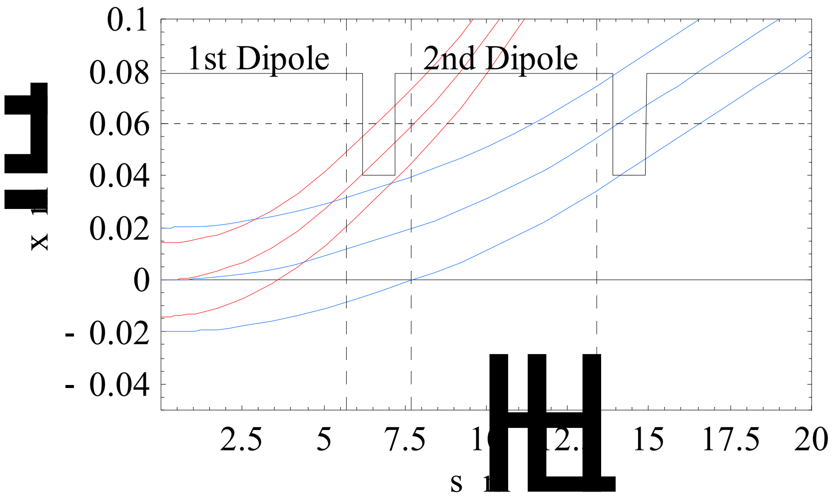
- Primary cross sections are highest in the region of ΔZ=-1 to -3, ΔA=-1 to -3
  - Momentum/charge will change dramatically, eases separation
- With the light ions used the probability is very small to have fragmentation ions within the acceptance
  - Dispersion region allows to dump the fragmentation ions
  - Requires tracking simulation to locate hot spots of deposition
- Even better situation for ^{6}He due to lower A and Z

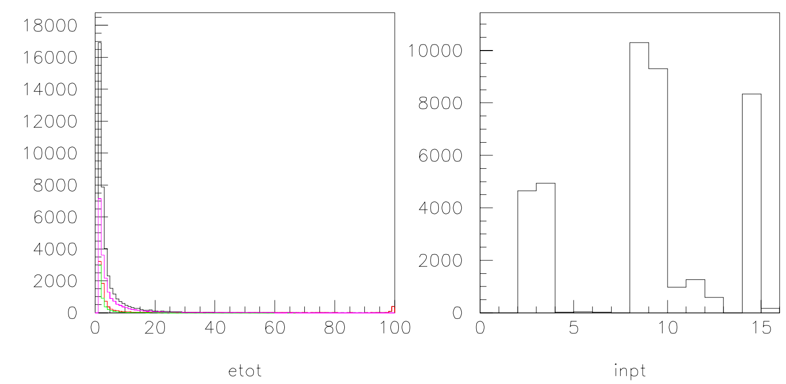
Absorbers

Absorb energy deposition
- accumulated from drift space in the arcs
- protect SC dipoles
- about 60 W per absorber

- Antoine showed the required aperture layout to allow perpendicular ion impact at absorber front face (maximized impact parameter)
  - Requires large dipole aperture > 8 cm
  - Good field region smaller (4cm)

- 1 meter long carbon jaws absorb major part of primary ions
  - Simulated primary proton impact is absorbed down to the percent level.





Conclusion

Immediate steps required to validate concepts:

- Momentum collimation
  - Maximize impact parameter by going to the limits of peak deposition power
  - Simulate fragmentation production at small impact parameter
  - particle tracking downstream for fragment deposition pattern

- Absorbers
  - 1 meter carbon is reasonable to reduce energy deposition in arcs
  - Dipole design with large aperture, relax on good field region
  - Study impedance effect on beam