Staged Approach to the NF

Chris Rogers,
Accelerator Science and Technology Centre (ASTeC),
Rutherford Appleton Laboratory

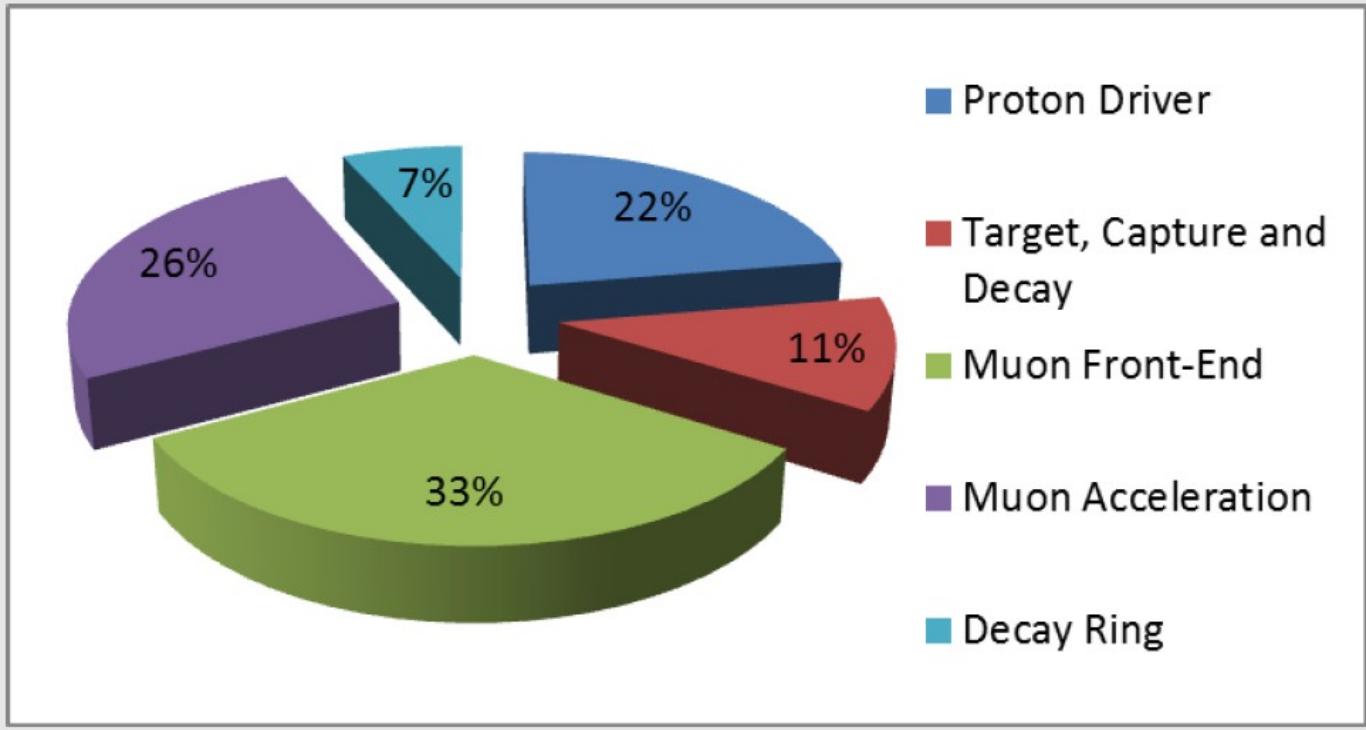
(July 3, 2012)

Jurgen Pozimski,
EuroNu June 2012

Overall Cost – for discussion

"cum grano salis"

- Proton driver
- Target
- Front End
- Muon acceleration
- Decay ring



black = similar for all facilities (SB plus β–beam)

blue = similar with β-beam (the cost for LENF rather half - 1/3)

red = NF only

Upgrade Scheme

- Comment from physics group at IDS Glasgow
- Even with neutrino flux reduced by ~ factor 25, NF is competitive with LBNE superbeam
- LBNE cost estimate is $2.6 Billion
- Without stating the secret cost number that everyone knows... but NF looks competitive with LBNE at least
- Can we consider an upgrade scheme that can improve things?

Things That Are Expensive, Risky

- Main technical risks:
  - Cooling channel
    - Also “perceived” as a technical risk by community due to MICE
  - Target station
    - Though risk is decreasing as design matures
- Big cost to performance ratio item:
  - Cooling channel
- It would be nice if we could put these items in an upgrade path
- Just taking the cooling channel out is undesirable
- Can we use the chicane to do something clever?

3.2 Helical Motion

In the presence of a field of this nature, some particles can be shown to travel in a helix. Starting from the Lorentz equations,

$$\vec{F} = \frac{d\vec{p}}{dt} = q\vec{v} \times \vec{B} \tag{4}$$

it is possible to derive the criterion for helical motion. Assume no radial velocity, so that

$$\vec{v} = c\frac{p_y\vec{y} + p_s\vec{s}}{E} \tag{5}$$

with speed of light c. Then if the particle is travelling at radius ρ

$$\vec{F} = qc\frac{p_y b_0}{E\rho} \tag{6}$$

For circular or helical motion, with constant energy,

$$\vec{F} = m\gamma\rho\omega^2 = \frac{m\gamma\beta_s^2c^2}{\rho} = \frac{c^2p_s^2}{Er_0}. \tag{7}$$

By equating the two expressions for $\vec{F}$

$$\frac{c^2p_s^2}{E\rho} = qc\frac{p_y b_0}{E\rho}. \tag{8}$$

Then if

$$p_y = \frac{qp_s^2}{b_0} \tag{9}$$

$b_s = b_0/\rho = 1.5$ T

particle motion will be on a helix. It should be noted that the slope of the helix is independent of the radius.

3.3 Vertical Displacement

In a chicane-type geometry vertical displacement into a collimator used to reject high momentum particles. The vertical displacement is given by

$$\delta_y = \frac{dy}{ds}\delta_s \tag{10}$$

where δ_s is the total path length through the circular orbit,

$$\delta_s = \rho\delta_\theta \tag{11}$$

and δ_θ is the total bend angle of the chicane. The vertical divergence is given by

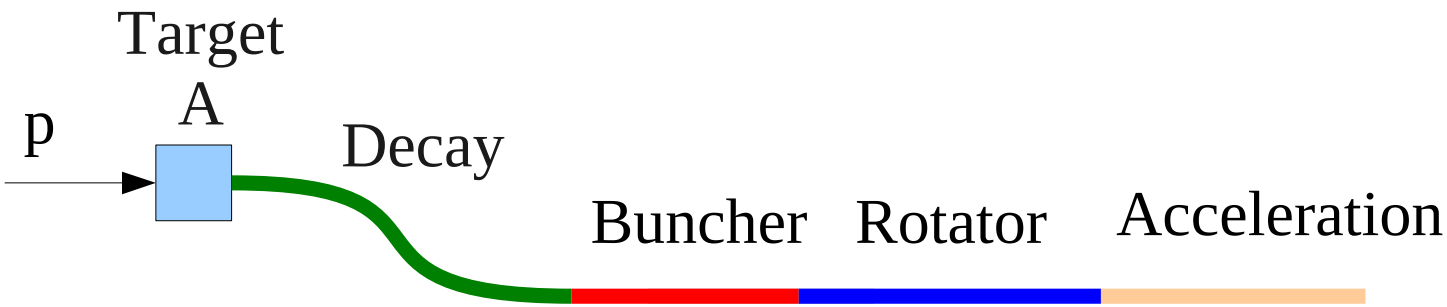
$$\frac{dy}{ds} = \frac{p_y}{p_s} = \frac{qp_s}{b_0} \tag{12}$$

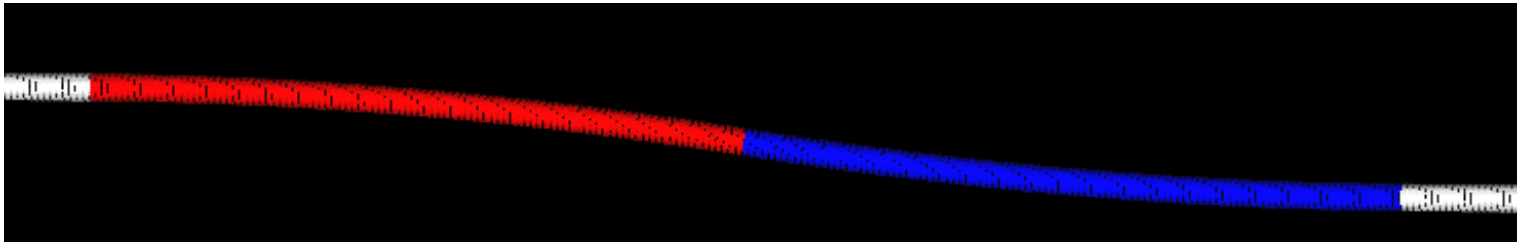
so

$$\delta_y = \frac{qp_s}{b_0}\rho\delta_\theta = \frac{qp_s}{b_s}\delta_\theta \tag{13}$$

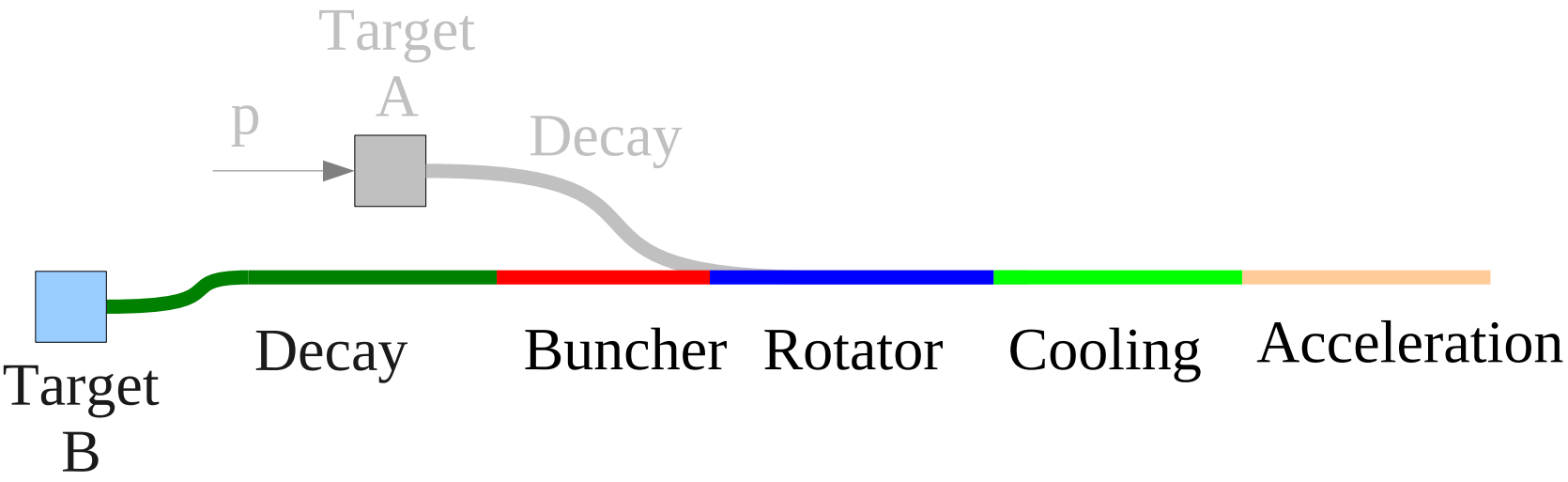
and the vertical displacement is a independent of the radius of the helix. This is a useful feature as the chicane can be designed to fit the available space by adjusting the radius of curvature as appropriate.

Concept – Stage 1

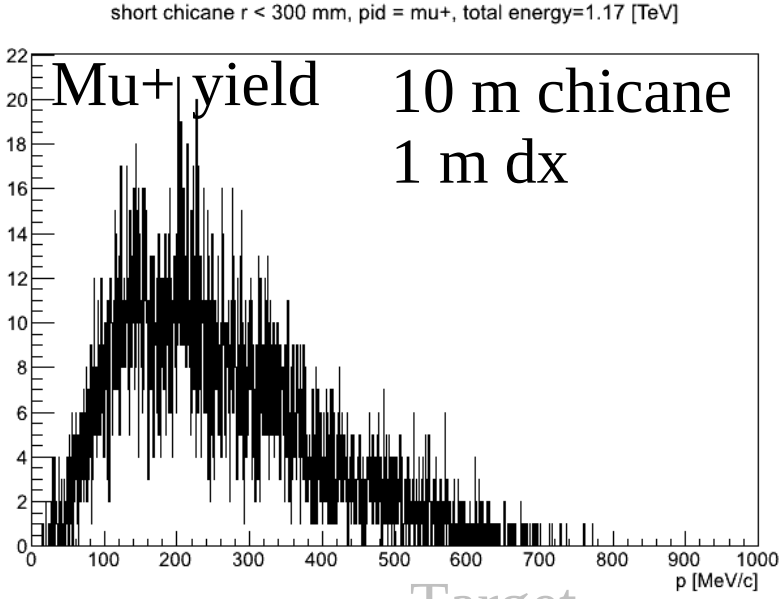


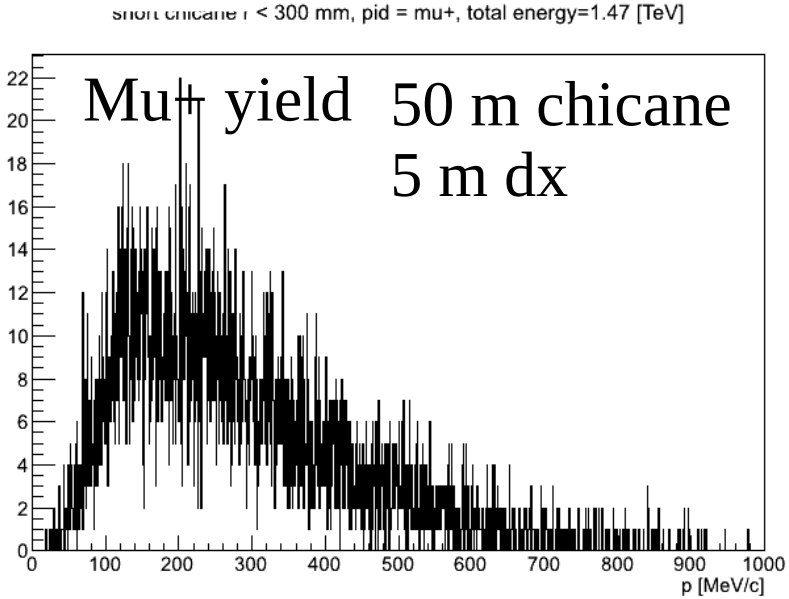


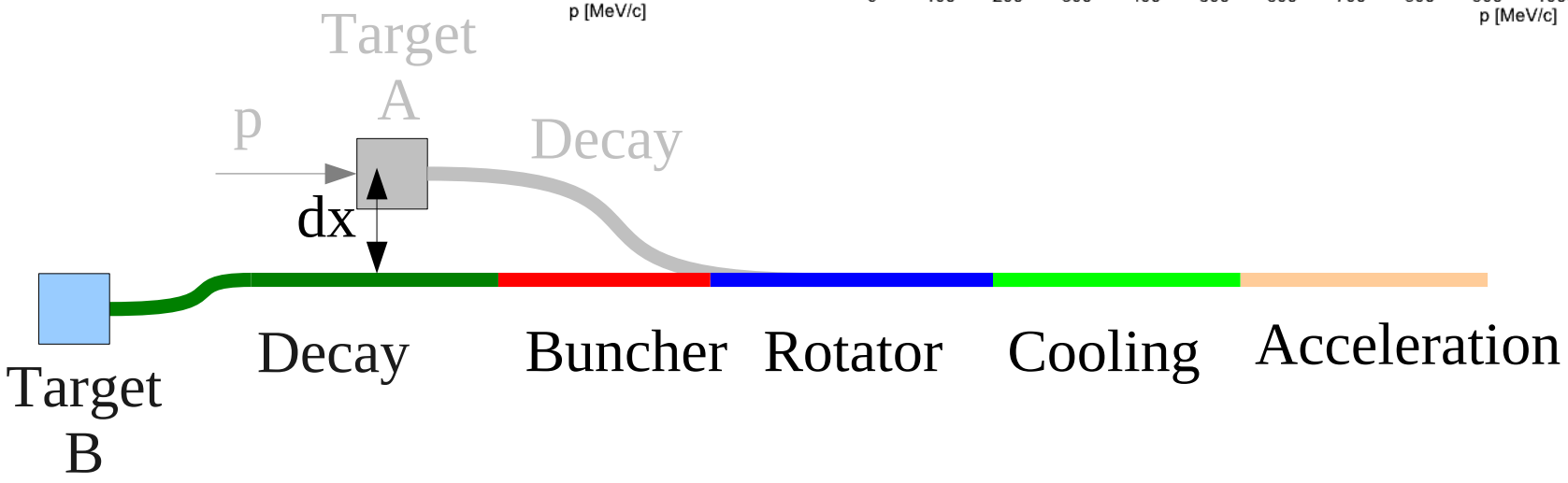
Concept – Stage 2



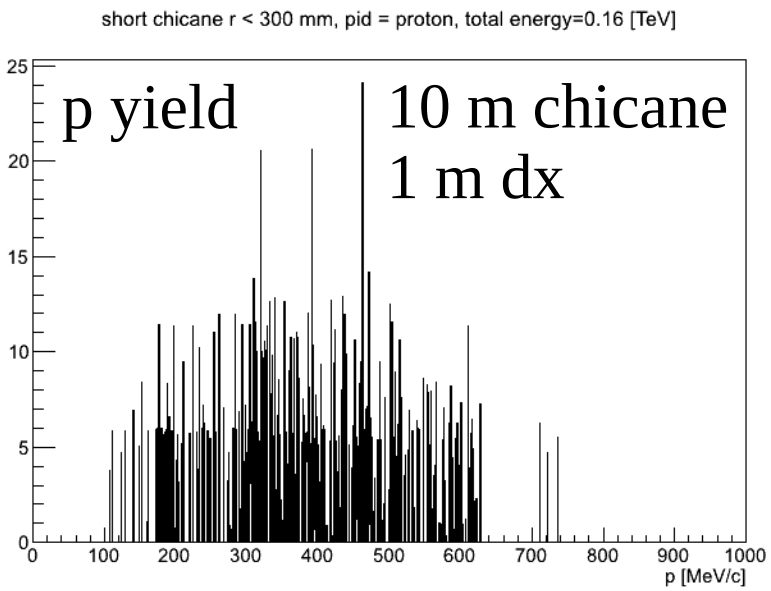
Does it really work?

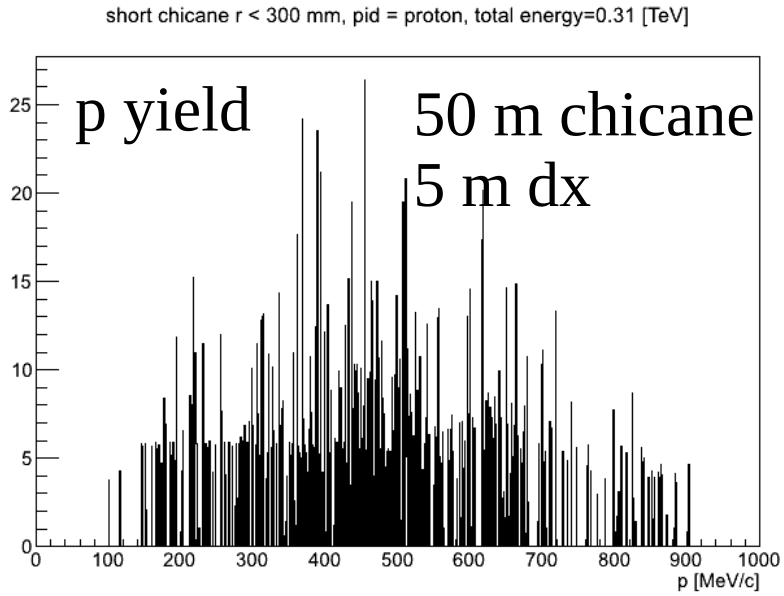


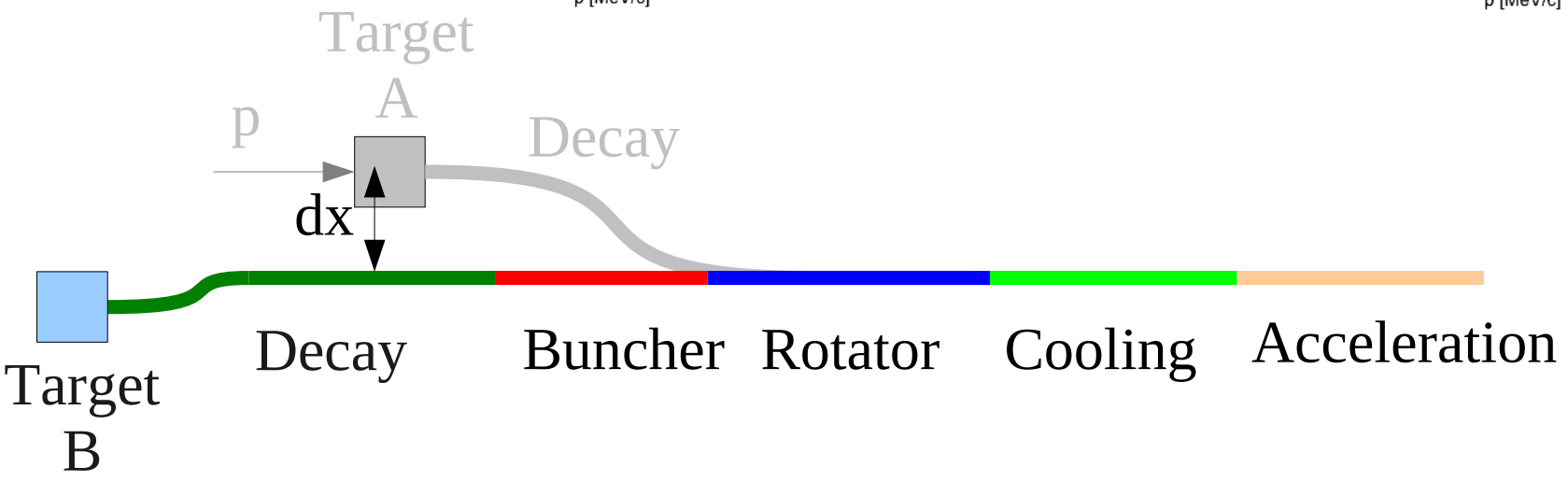




Does it really work?







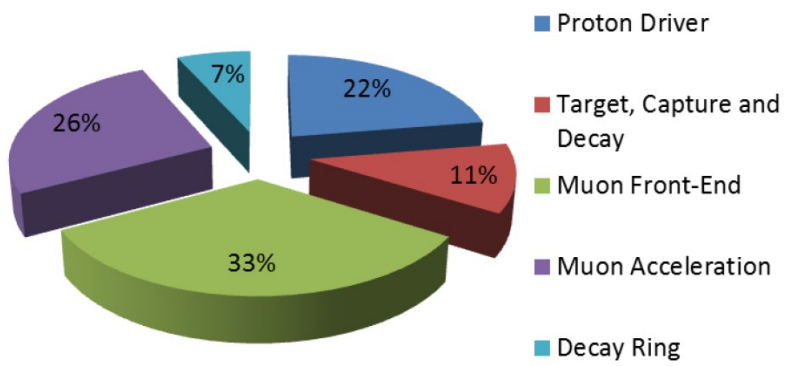
Comments

	Good muon yield (ecalc9f after p_abs)
100 m chicane	490
50 m chicane	574
10 m chicane	510.7

- Good muon yield is pretty stable
- Is 5 m enough room
  - Need to have space for target hall plus RF hardware in front end tunnel
- In reality, may prefer two chicanes
  - One for momentum collimation
  - One for geometry

Scheme

- LENF-
  - Use existing proton driver
    - Say Fermilab booster @ 700 kW
    - ~1/5 rate
    - Needs bunch compressor?
  - Remove cooling channel
    - ~1/2 rate
  - Use horn-type target
    - ~1/2 rate
- Overall ~ 1/20 rate
  - In line with physics requirements



	LENF-	LENF+
Proton driver	0%	22%
Target, capture, decay	5%	11%
Front End	10%	23%
Acceleration	26%	0%
Decay Ring	5 %	7%
Total	46%	63%