Staged Approach to the NF

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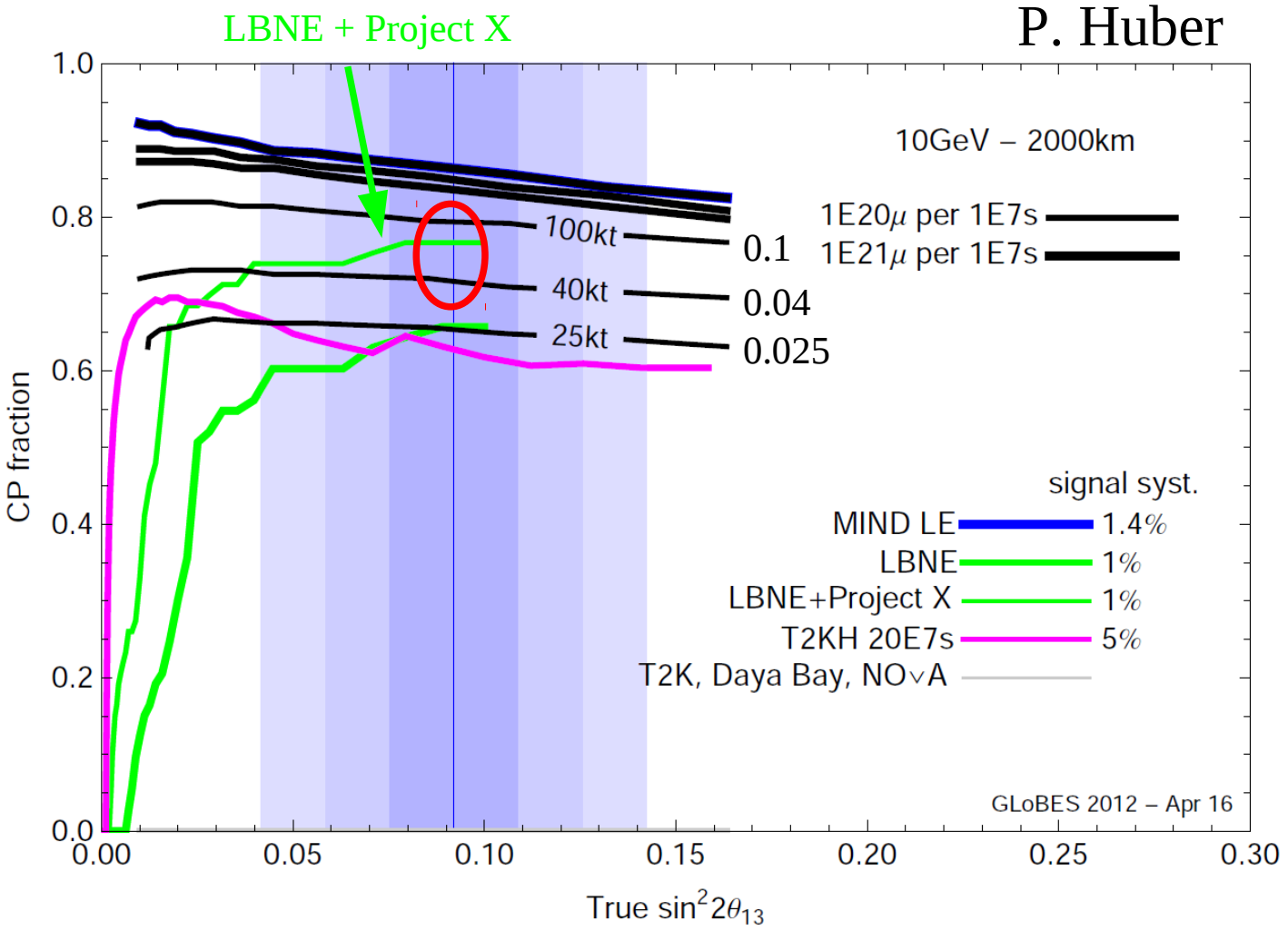
Staging Scheme for NF

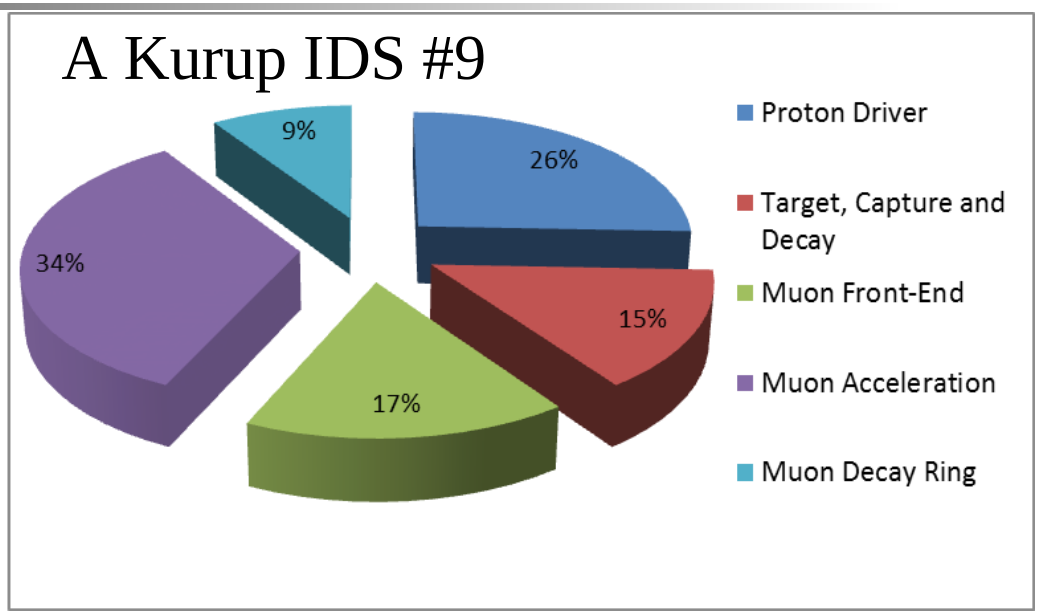
- 3 parameters/approaches
  - Number of muons in the decay ring
  - Muon final energy
  - Detector size (but not much comment in this talk)
- Need to decide here
  - What approach to take for staging
  - How to present in RDR
- Driven by tension between
  - Physics needs
  - Cost
  - Technical risk
- Try to assess the tensions and propose schemes
  - Expect new costing, physics results, etc to gazump my assessment
- NuStorm should be on the menu
  - But not discussed much here

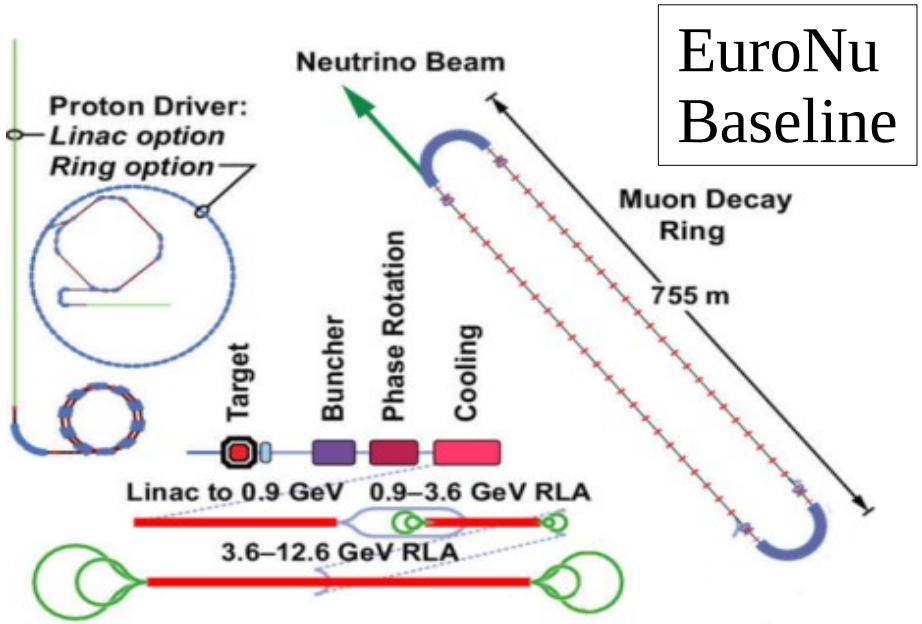
Physics Reach



Cost

- Base cost on EuroNu
  - 12.6 GeV Muons
  - Single decay ring
  - “Cum grano salis”
- Define cost unit (cu)
  - 1cu = 1% of euronu facility cost
- Needs updated baseline/costing
  - More comments later

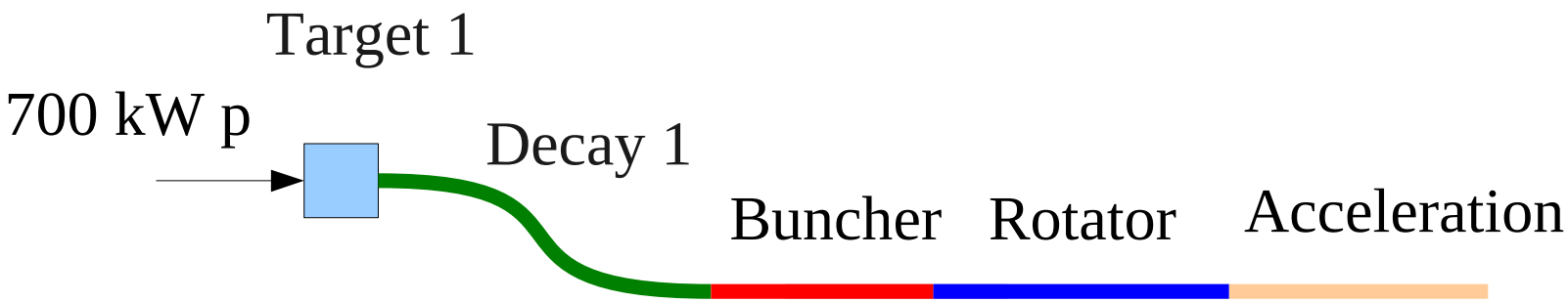




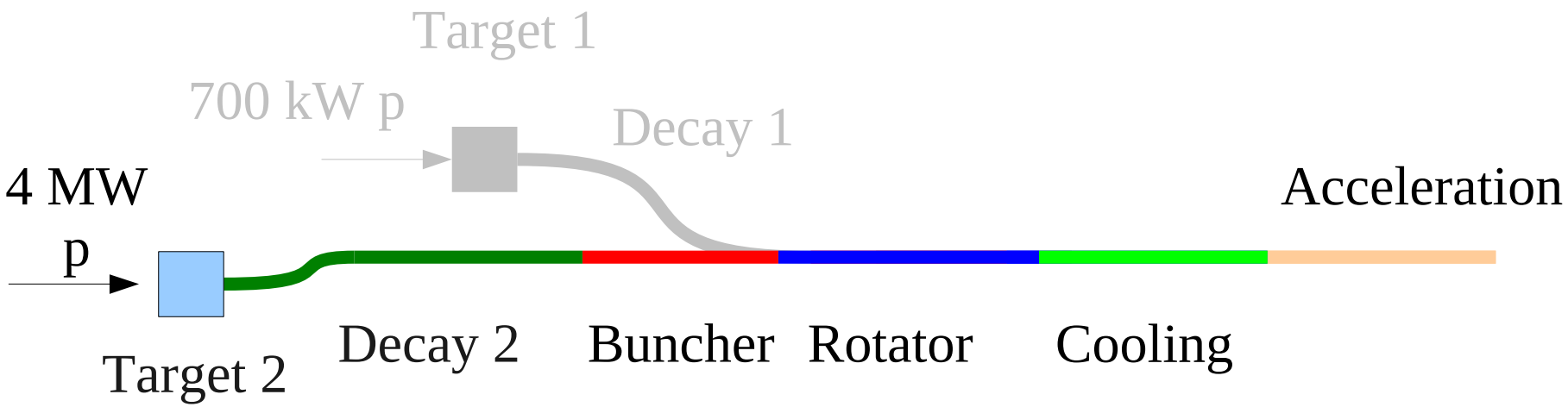
Things That Are Expensive, Risky

- Main technical risks:
  - Cooling channel
    - Also “perceived” as a technical risk by community due to MICE
  - Target station
    - 20 T magnet
    - Large aperture
    - Lots of beam power
- Big cost:
  - Cooling channel

Rate Staging – Stage 1

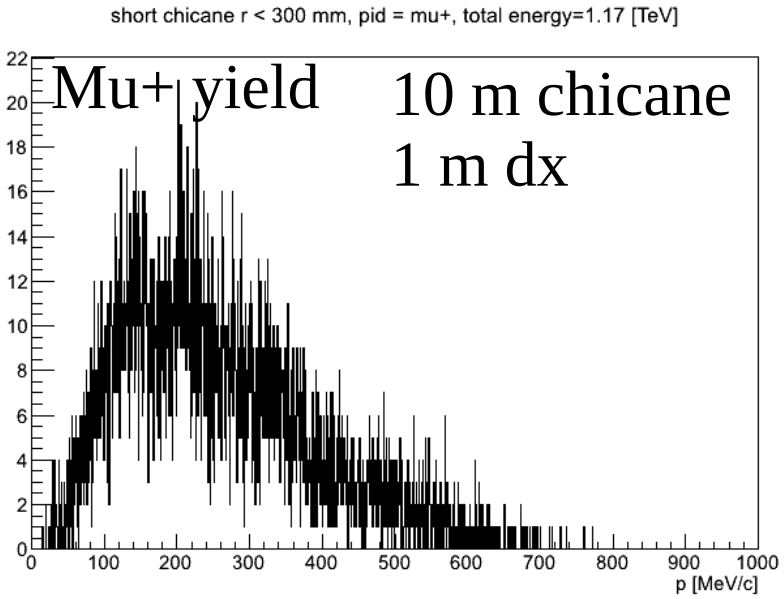


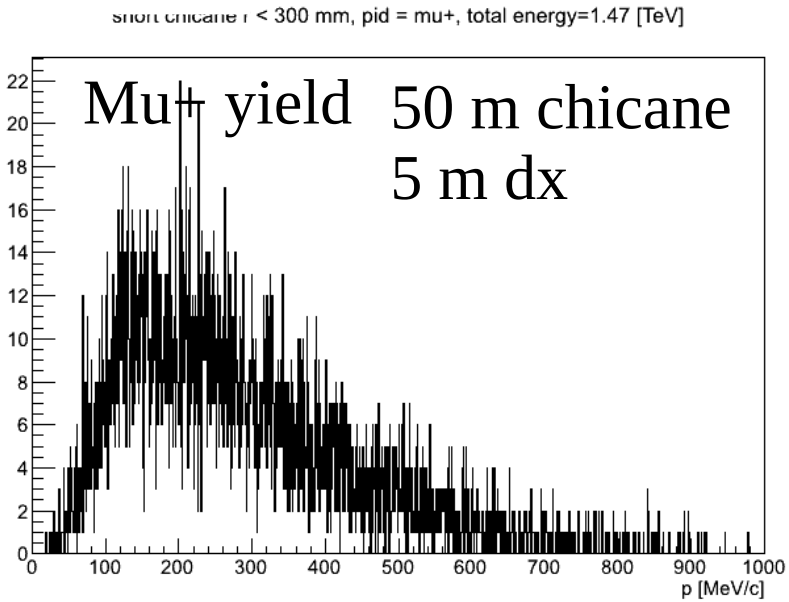
Rate Staging – Stage 2

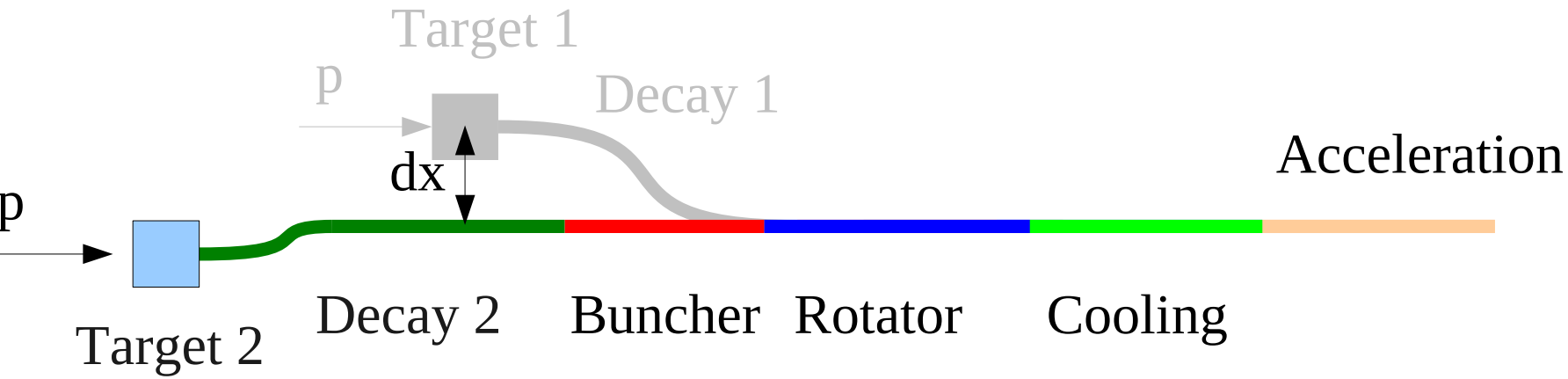


- Target station 1 could be a target horn
- Target station 2 could be a solenoid dual sign capture
- By moving the target back, we can now include cooling channel
- Solenoid chicane scaling law
  - Momentum collimation dependent on bending angle
  - Momentum collimation independent of radius of curvature

Practical Issues



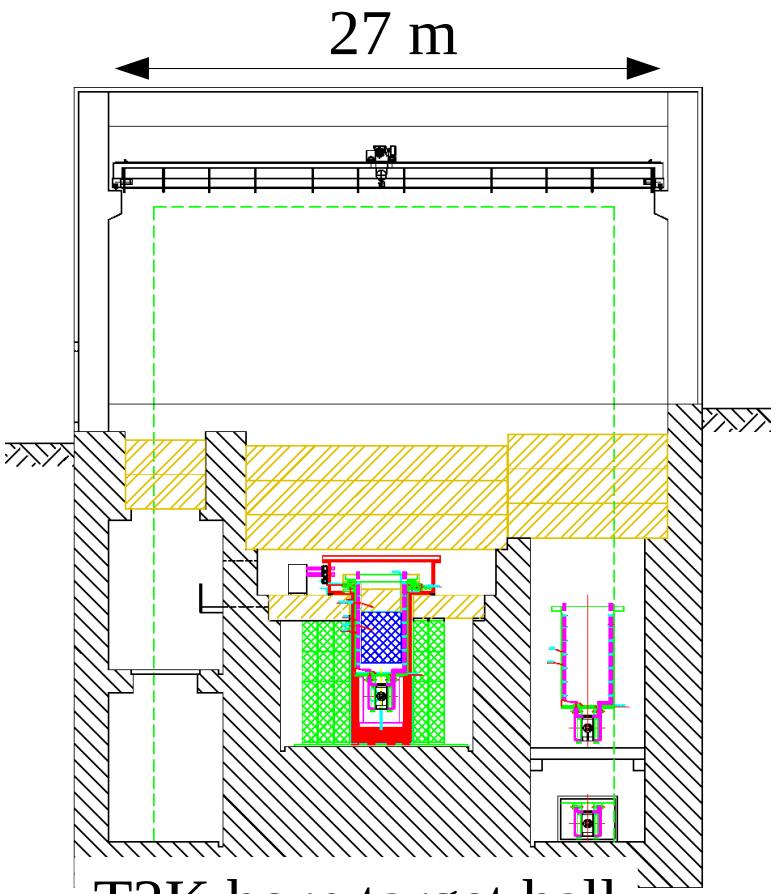




Comments

- Good muon yield is pretty stable
- Is 5 m enough room
  - More aggressive chicane design?
  - Vertical bend?
  - E.g. T2K target hall
- May prefer two chicanes
  - One for momentum collimation
  - One for geometry
- Few extra costs/designs required
  - Proton driver transfer line
  - Decommissioning of target 1/decay 1
  - Removal and recommissioning of Buncher + Phase Rotator
  - Not major costs

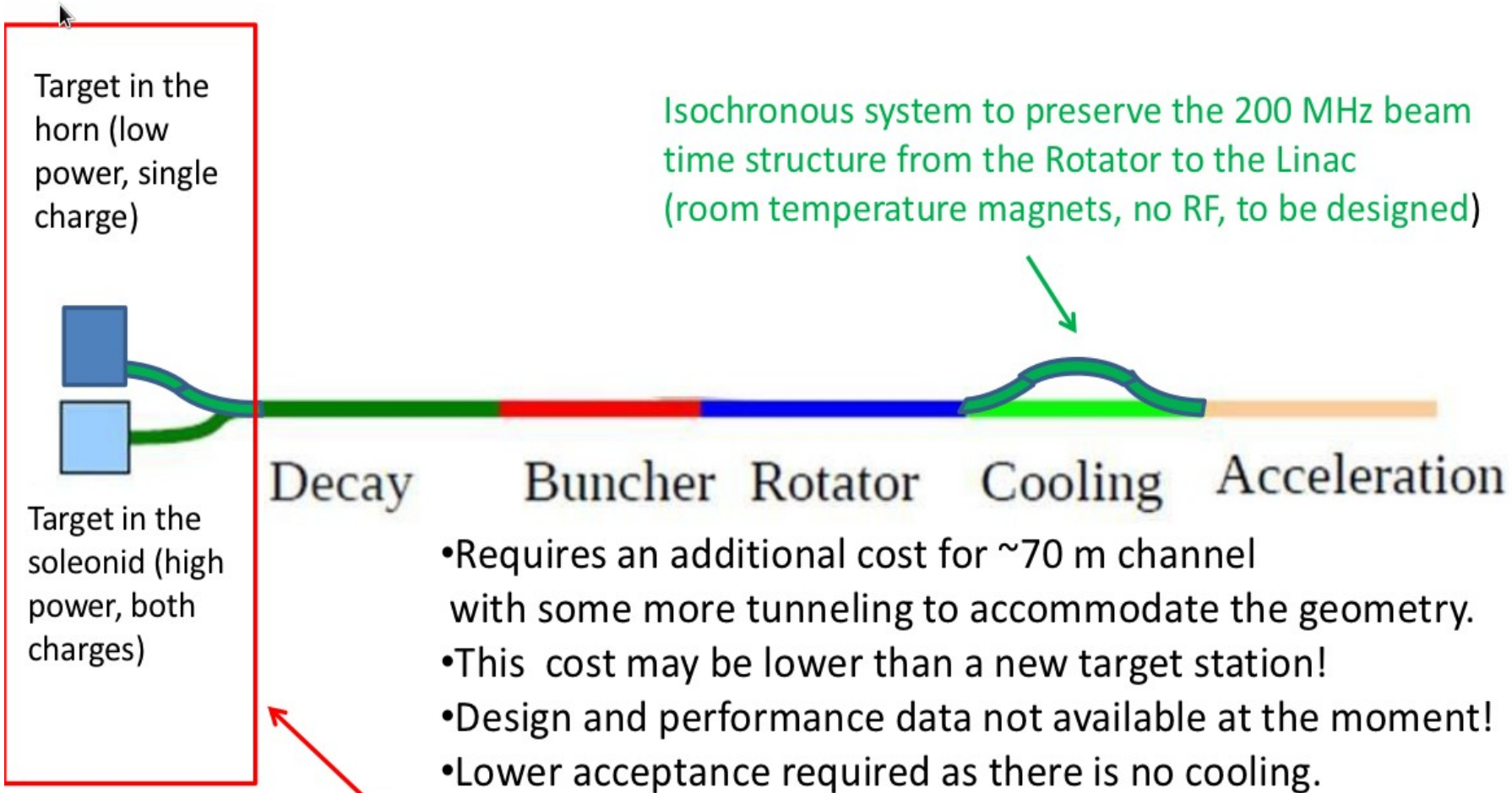
	Good muon yield after proton absorber
50 m chicane	574
10 m chicane	510.7



T2K horn target hall

Alternative Idea for the Layout

Jaroslaw Pasternak

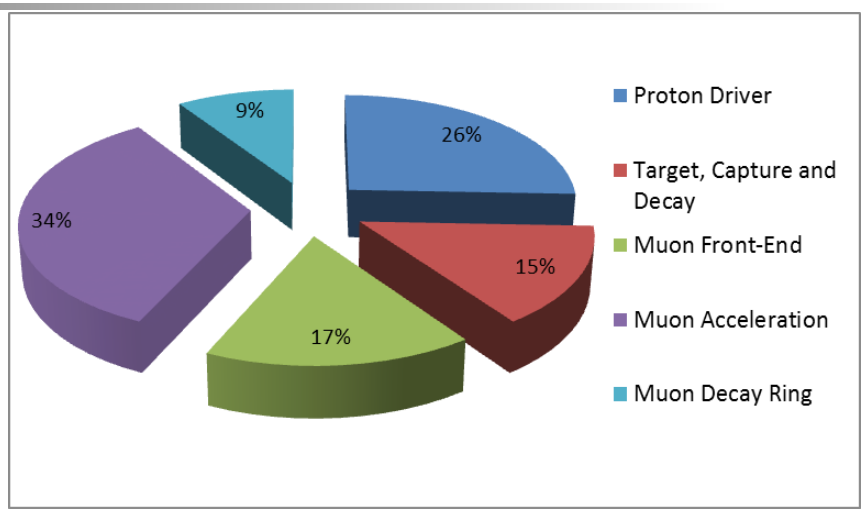


- Requires an additional cost for ~70 m channel with some more tunneling to accommodate the geometry.
- This cost may be lower than a new target station!
- Design and performance data not available at the moment!
- Lower acceptance required as there is no cooling.

Common target station with two cells

Rate staging scheme - costs

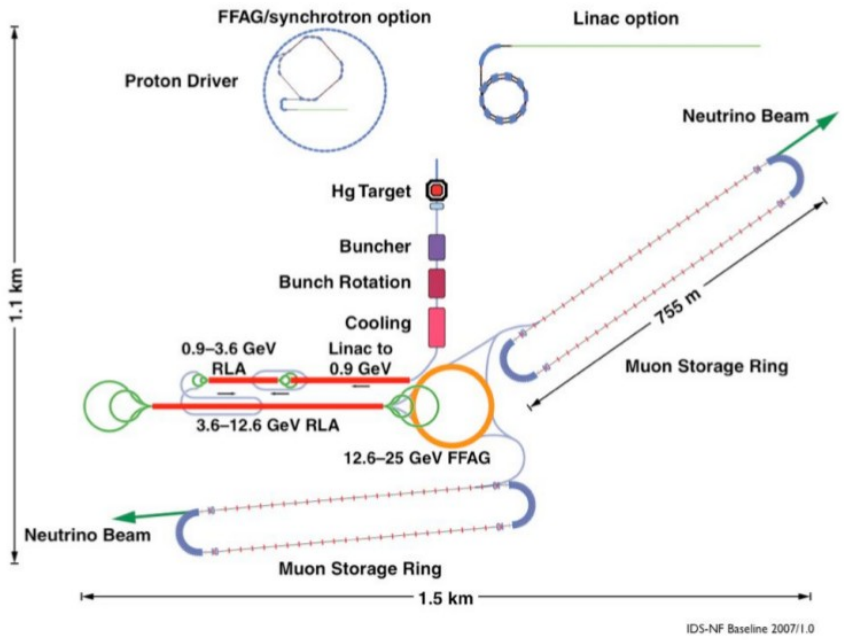
- Stage 1
  - Use existing proton driver
    - Say Fermilab booster @ 700 kW
    - ~1/5 rate
    - Needs bunch compressor
  - Remove cooling channel
    - ~1/2 rate
  - Use horn-type target
    - ~1/2 rate
- Overall ~ 1/20 rate
  - In line with physics requirements
- Proton driver upgrade independent of other items
  - Do it first as it is cheapest/rate
  - Leads to extra physics options
    - Rare decay experiments etc
- Nb: acceleration is likely cheaper

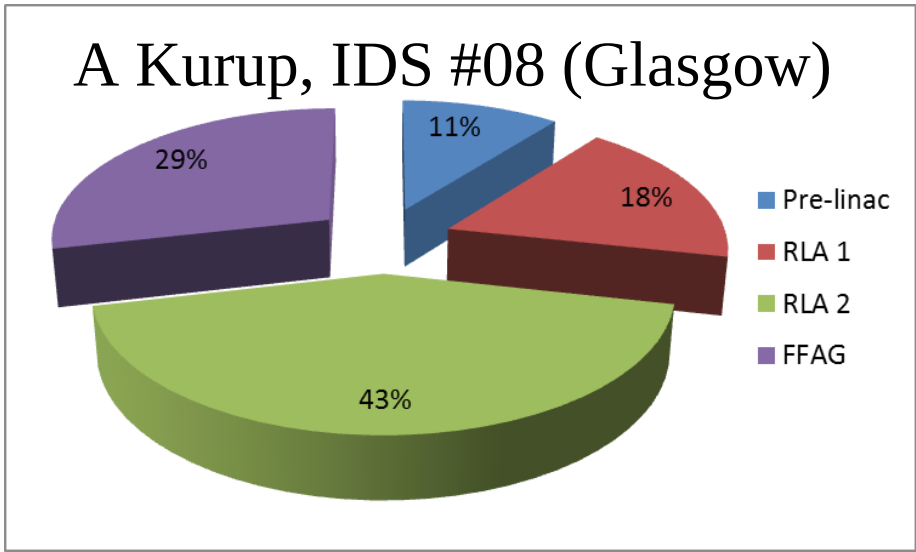


	Stage 1 [cu]	Stage 2 [cu]
Proton driver	6	21
Target, capture, decay	8	15
Front End	6	12
Acceleration	34	0
Decay Ring	9	0
Total	63	48

Energy Staging Scheme

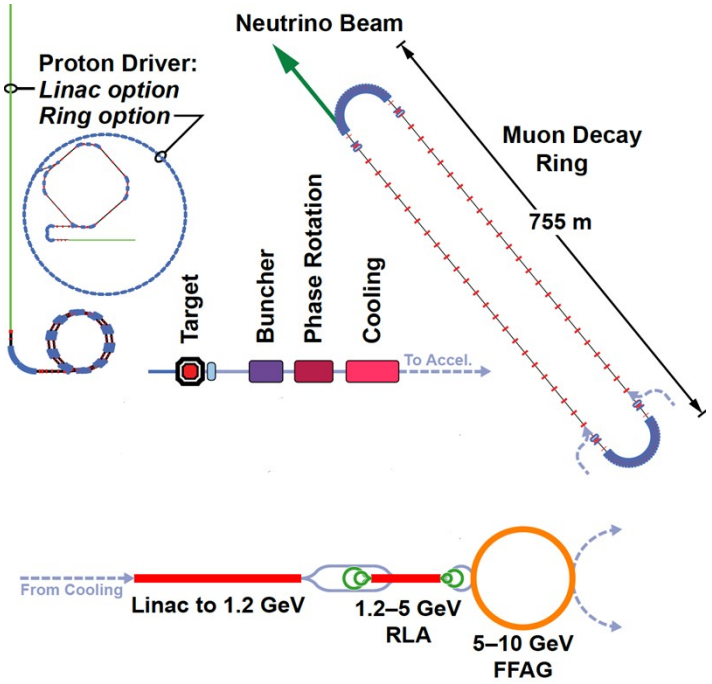
- Costing is for IDR baseline
  - 25 GeV acceleration





Energy Staging Scheme

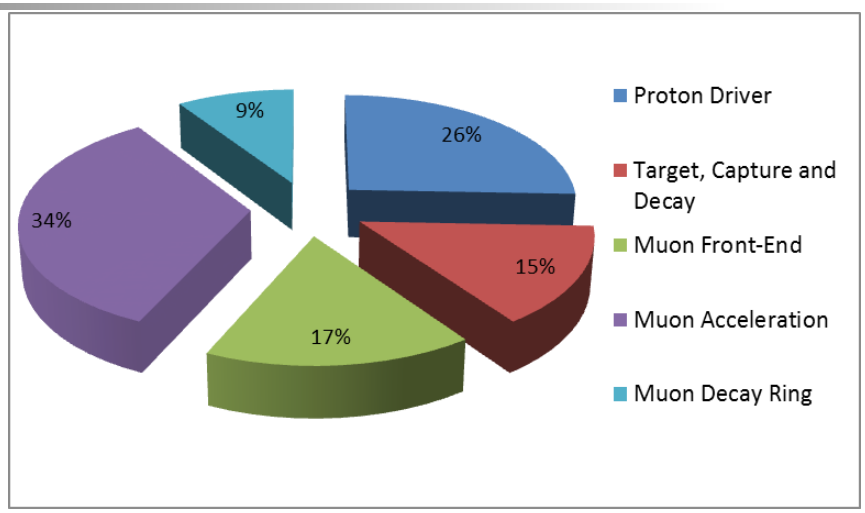
- Scale to 10 GeV acceleration
- Assume Pre-linac and RLA cost scales with energy
  - Assume the same number of arcs
  - Just make the linacs longer
- Assume FFAG cost scales with circumference
  - Voltage per turn ~ circumference
  - Civil costs ~ circumference
- Two designs for FFAG
  - 12.5-25 GeV design => 670 m
  - JS Berg preliminary design 490 m
  - J Pasternak preliminary design 330 m
- Total is either 19.8 or 23.9 cu
  - Compare with EuroNu costing 26 cu



	Cost [cu]
Pre-Linac	7.3
RLA	11.9
Berg FFAG	12.0
Pasternak FFAG	6.7
Total	25.9/31.2

Energy Staging Scheme - Costs

- Physics reach dependence on energy unclear
- But staging here doesnt gain much
  - Need to rebuild decay ring for higher energy
  - Cost of final 5 GeV of acceleration is at worst 9 cu
- Potential in combination with a rate staging scheme?
- Potential in combination with existing decay ring (NuStorm)?



	Stage 1 [cu]	Stage 2 [cu]
Proton driver	26	0
Target, capture, decay	15	0
Front End	17	0
Acceleration	19	12
Decay Ring	9	9
Total	86	21

EuroNu Context

Staged approach to a Neutrino Factory

We envisage a staged approach to delivering a 4 MW, 10 GeV Neutrino Factory, with important physics possibilities at each step. The stages are:

1) nSTORM [12]. This project will use an existing proton driver of around 300 kW beam power to create pions in a target. Forward going pions with an energy of 5 GeV (±10%) will be focussed into a transport line, before injection into a straight of a storage ring. Muons of around 3.8 GeV from the decay will then be transported around the ring and the neutrinos from their decay used for the following studies:
   - the search for sterile neutrinos,
   - the measurement of $\nu_e N$ scattering cross-sections,
   - neutrino detector development.

   In addition, this facility will be a valuable prototype for the Neutrino Factory construction. An LoI for nSTORM has recently been submitted to the FNAL PAC [12].
2) A low power version of the Neutrino Factory, using an existing proton driver, without muon cooling and using a lower mass MIND detector, around 20kt. This will already have a very competitive physics potential [13].
3) A 4 MW Neutrino Factory using 10 GeV muons and a 100 kt MIND detector at a baseline of around 2000 km.

Discussion

- Should we reference a staging scenario in RDR?
- What should the staging scenario be?
- How should facility be presented in RDR?
  - Do we do lattice design for Stage 1 and Stage 2?
  - Do we do costing for Stage 1 and Stage 2?
  - Mostly front end group + costing that gets the extra work...
  - Do we present Stage 1 as an appendix?
  - Is there an optimisation between e.g. cooling and detector size – i.e. is it cheaper/easier to make 200 kT MIND
- How should PPEG be presented in RDR?
  - Physics case for both?
  - In an appendix?

Discussion

- Assert – for discussion
  - Full NF looks demanding to fit within today's budget constraints
  - Stage 1 NF seems more hopeful to get funded
  - Therefore staged NF should be the RDR baseline
- Assert – for discussion
  - Staging on energy appears to be a mistake
  - Staging on rate
    - Two stages as discussed
    - Three stages may be better
      - Basic machine (“Stage 1” above)
      - Proton driver upgrade
      - Cooling channel + target upgrade
  - Staging on detector
    - I dont know detector cost vs accelerator facility cost
    - Staged detector has some risk mitigation benefit