WG3 Summary

Megan Friend, Sudeshna Ganguly, Maja Olvegård

September 6, 2025

Liverpool, UK

Working Group 3: Accelerators

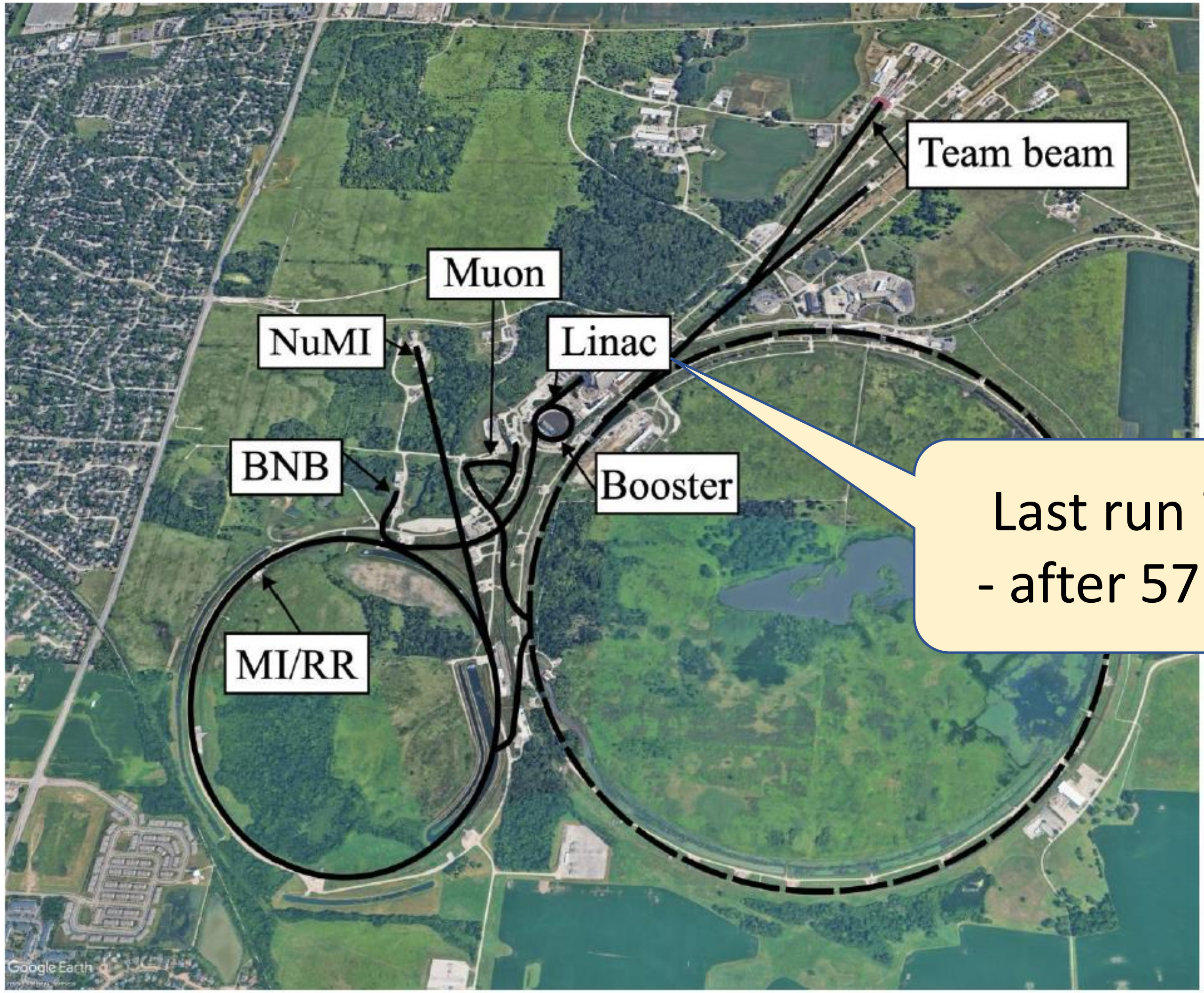
- Three plenary talks (Monday+Friday)
- 6 parallel talks, pure WG3
  - nuSTORM facilities (Tuesday)
  - Targetry and instrumentation (Thursday)
- 4 parallel talks WG3 + WG4 – covered by WG4 summary (Tuesday)
- 3 parallel talks WG1 + WG3 (thursday

Fermilab Accelerator Complex

Alexander Valishev

Multi-purpose facility

- High Intensity Neutrino experiments
  - 120 GeV protons from MI
  - NOvA
- Low energy Neutrino experiments
  - 8 GeV protons from Booster
  - Microboone, SBND, ICARUS
- Muon Campus
  - 8 Gev protons from RR
  - g-2, Mu2e
- SY120
  - 120 GeV protons via slow extraction
  - Teambeam, Spinquest, MCenter

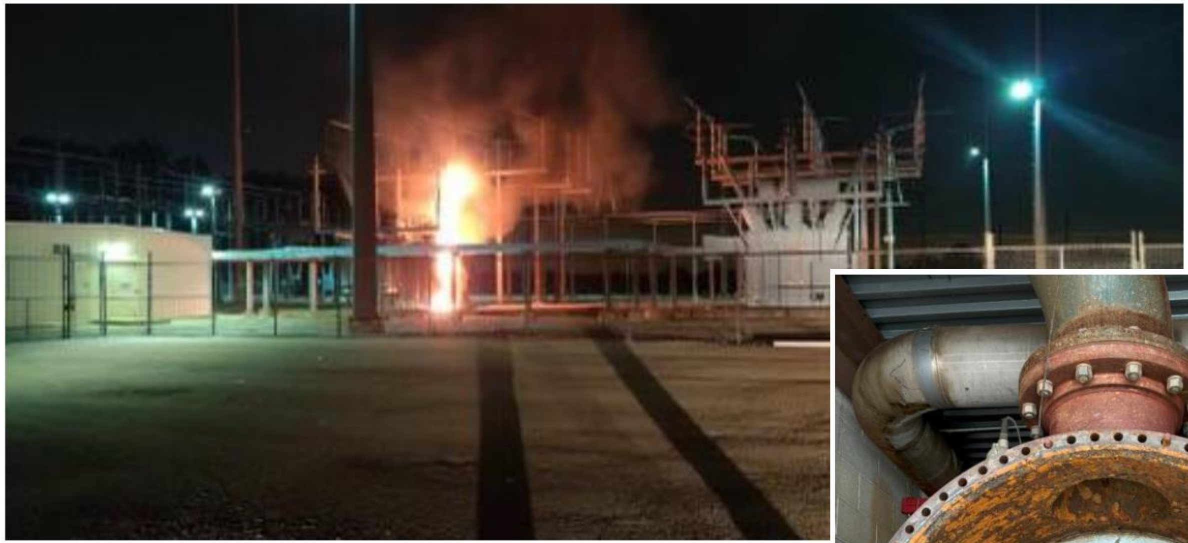


Last run i 2027
- after 57 years!

Fermilab Recent Challenges

Alexander Valishev

- Transformer failure
  - Variety of issues identified
  - Replacement with long lead times
- Corrosion in heat exchangers providing cooling water



➢ Need to modernize aging systems

The PIP-II Era

Alexander Valishev

DUNE expects 1.1E21 protons a year at 1.2 MW

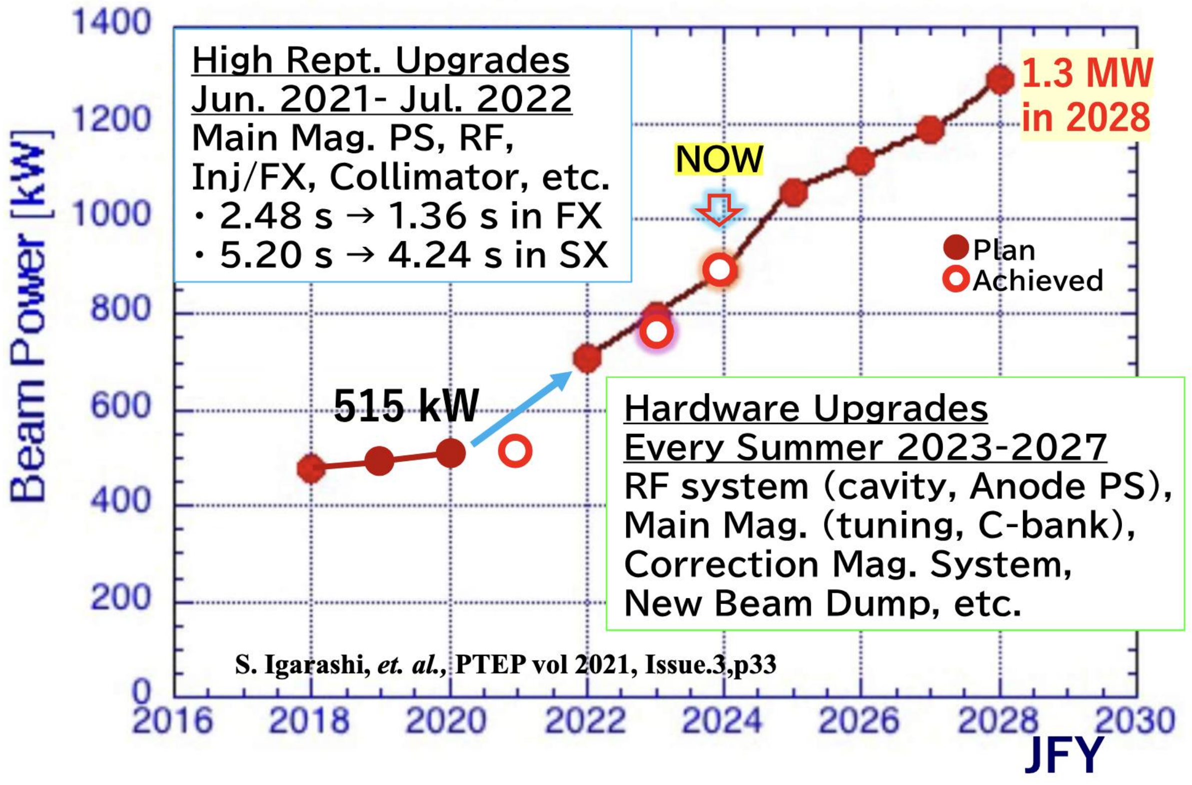
— Upgrade to 2.4 MW after 6 years

1. New superconducting linac
   - from 400 MeV to 800 MeV at booster injection
2. Booster cycle upgrade from 15 Hz to 20 Hz
3. 50% higher intensity in Main Injector
4. New beam line and target station to the LBNF

J-PARC: Road to 1.3 MW by 2028

Megan Friend

1. Reduce time between beam spills from 2.48 s to 1.16 s
   - Upgrade of RF and magnet powering systems
2. Improve beam stability -> allow for higher intensity
   - New beam optics in Main Ring reduces losses
   - New collimators, correction systems



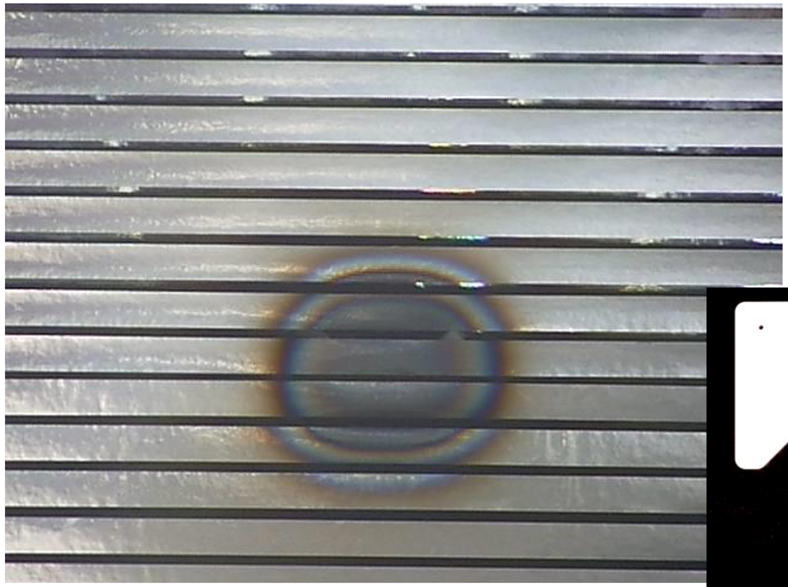
J-PARC: target and horn modifications

Megan Friend

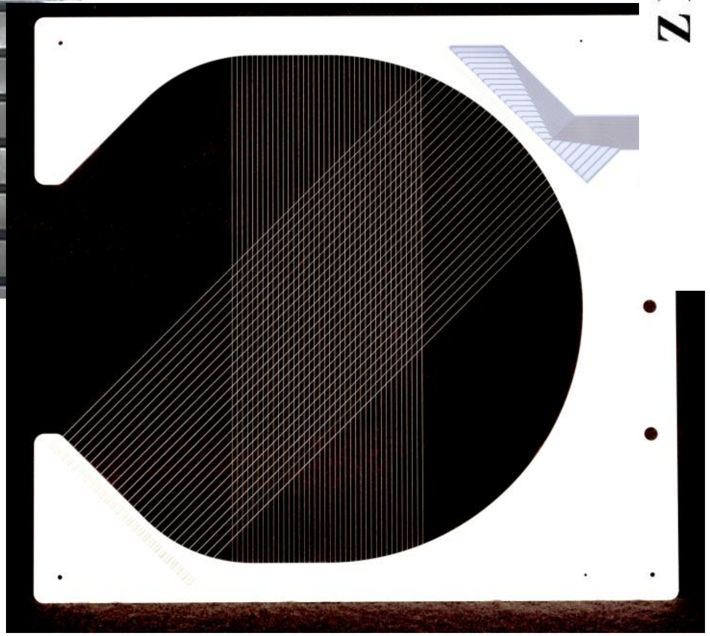
- Bolt locking device installed after helium leak
  - Downtime march-november 2025
  - Possible reason: vibrations and thermal cycling
- New target design, increased helium flow, pressure balanced pipes
  - Installation summer 2026
- Water-cooled striplines to feed current to horn 2 installed 2022
  - Current raised from 250 kA to 320 kA
  - 10% increase in right-sign neutrino flux
  - 5-10% reduction in wrong-sign neutrino flux
- DAQ upgrade to handle higher rep rate

J-PARC: Proton Beam Instrumentation

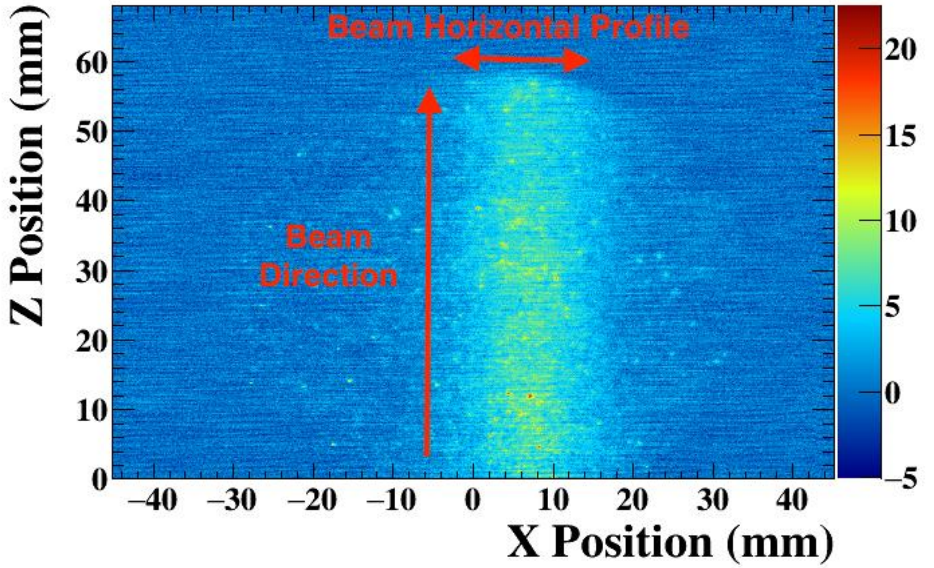
Megan Friend



Foil-based SEM grid



Wire-based SEM grid

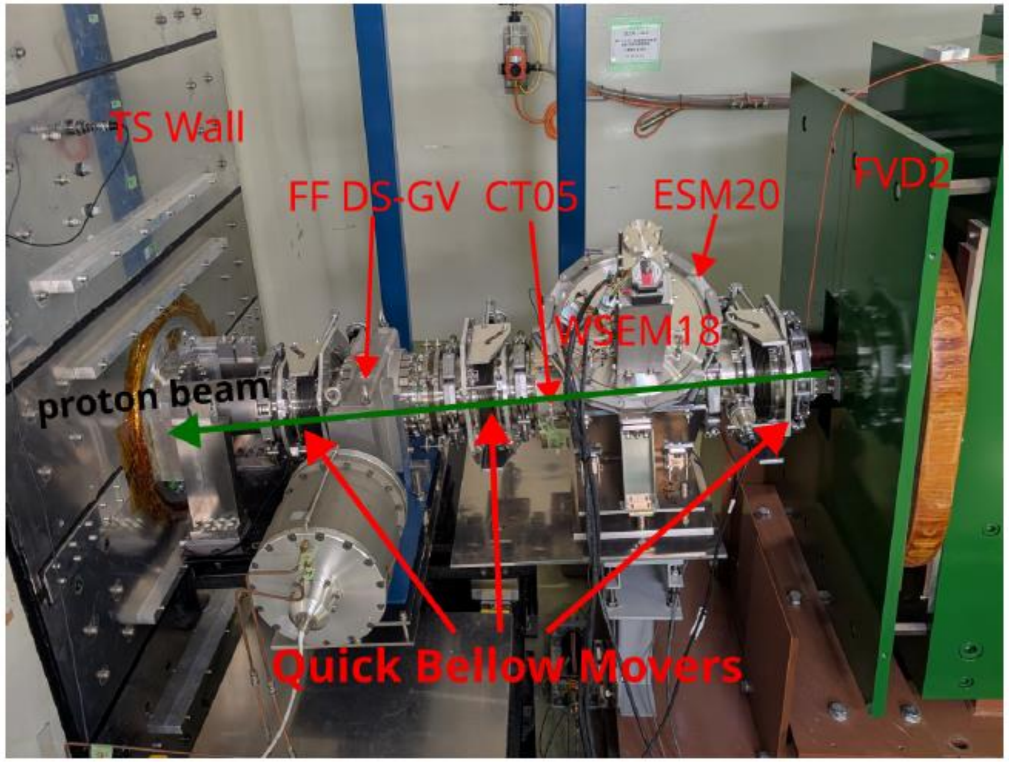


Beam-induced fluorescence monitor

J-PARC: preparing for Hyper K

Piotr Podlaski

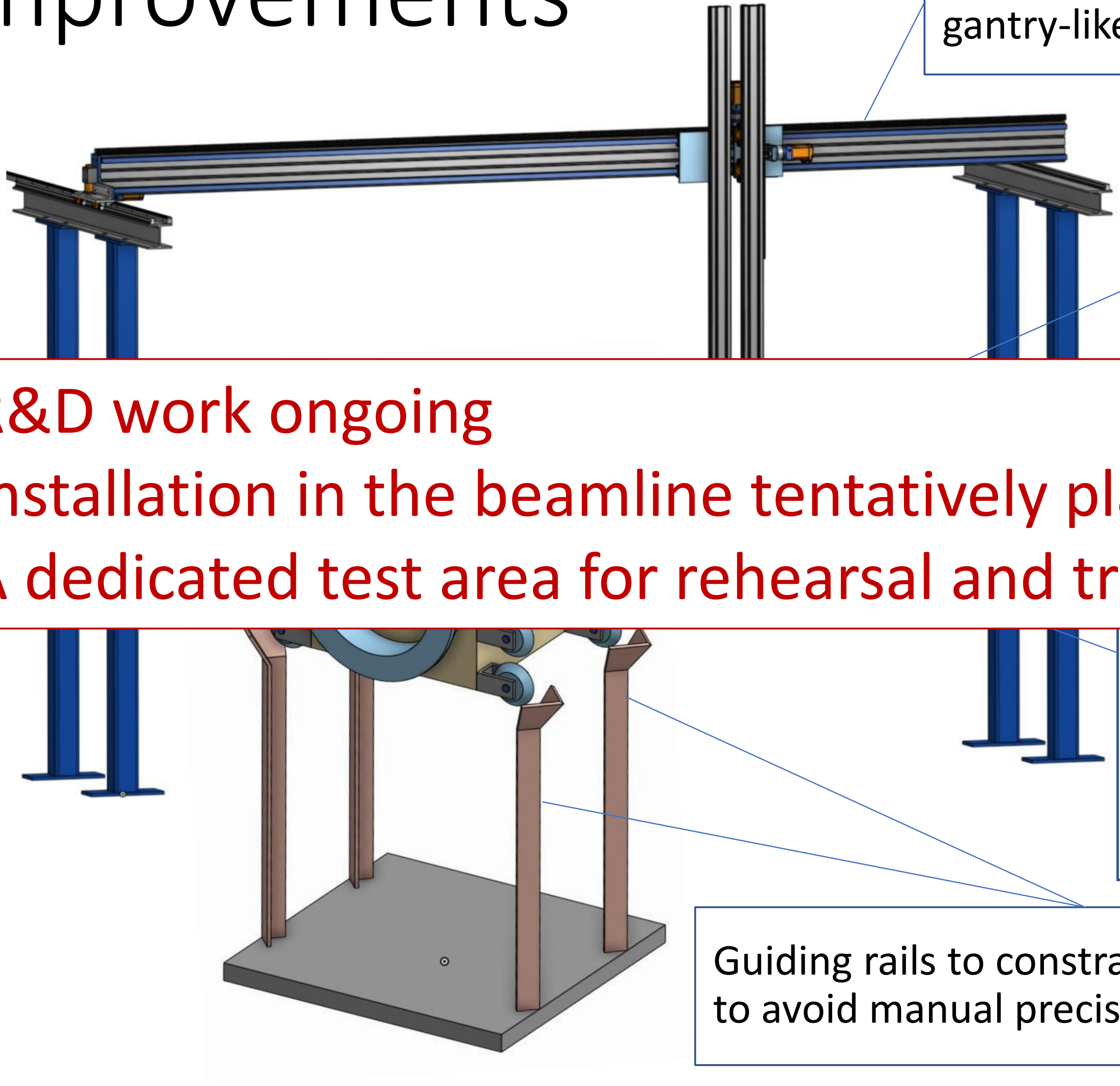
Remote handling/maintenance of last part of proton beamline



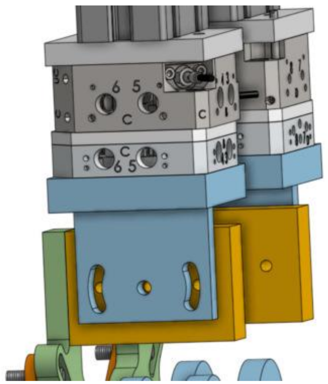
High radiation level, backscattered particles from target station

- Beam position monitor - ESM20
- Beam profile monitor - WSEM18
- Beam current monitor - CT05
- Final Focusing section Downstream Gate Valve separating primary and secondary beamlines – FF DS-GV

Improvements



Remote-controlled gantry-like manipulator



Commercial robotic tool-changer, with pivoting joint

- R&D work ongoing
- Installation in the beamline tentatively planned for summer-fall 2026
- A dedicated test area for rehearsal and training work will be built

New flange clamps to facilitate handling, increased visibility, tested at good performance

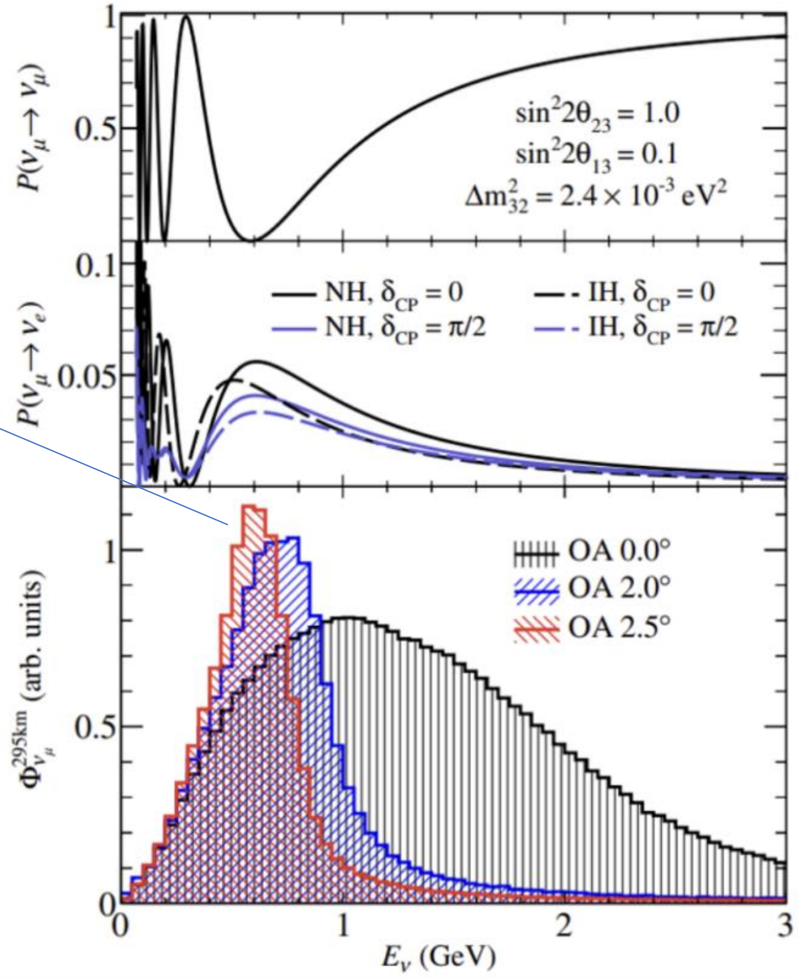
Guiding rails to constrain the movement, to avoid manual precision steering

Piotr Podlaski

J-PARC neutrino beam instrumentation

Ian Heitkamp

- Muon monitors for checking
  - Neutrino beam direction
  - Beam position on target
  - Neutrino flux
- 7x7 Silicon PIN photodiode array
- 7x7 Ionization chamber array
- Development of radiation hard Electron Multiplier Tubes to replace the PIN diodes in the Hyper-K era.

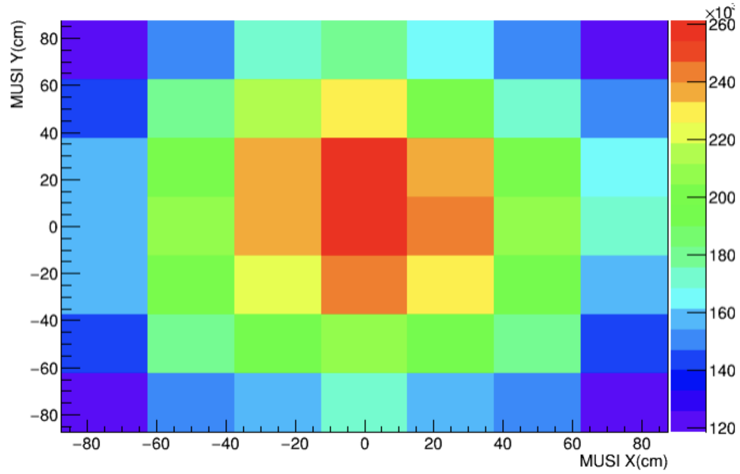


Muon and Neutrino Beam Monitoring

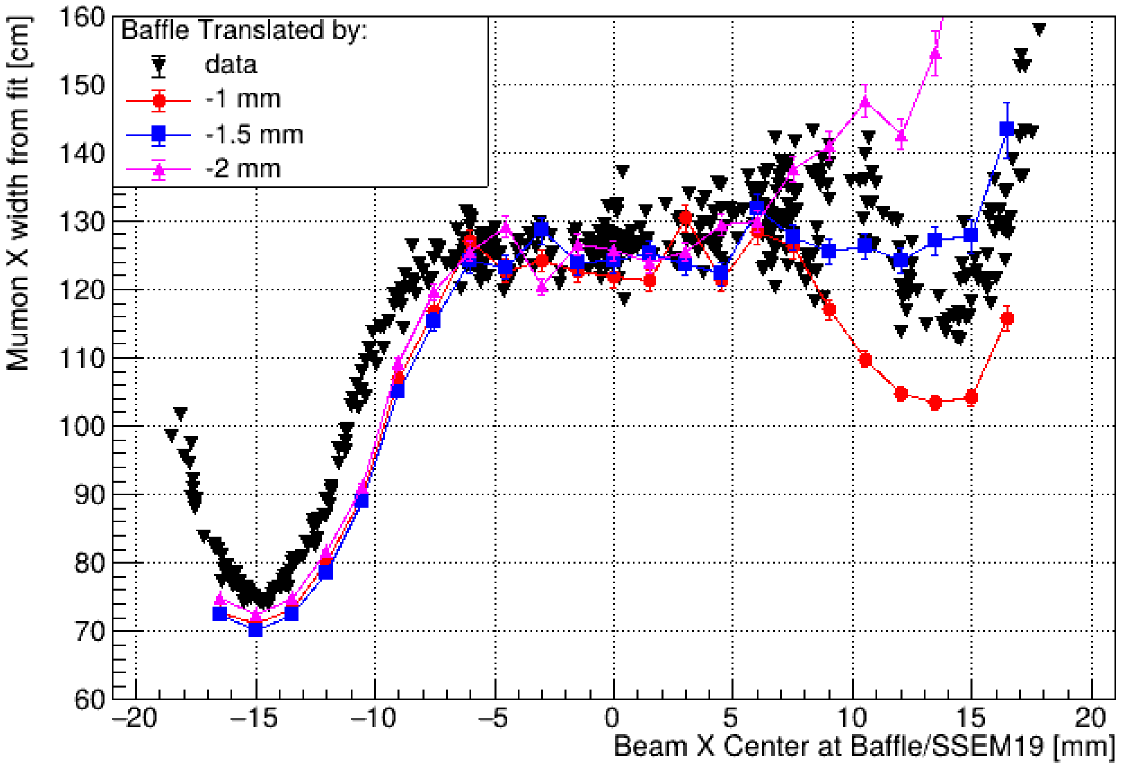
Ian Heitkamp

- Simulations of relative misalignment with FLUKA/JNUBEAM
- Compared with measurements
- Work in progress

Muon monitor measurement



Mumon Width Scan 0 kA Horn Current



Hadron and Neutrino Flux

Ian Heitkamp

Alysia Marino

- Neutrino flux not well modelled by Monte Carlo simulations
  - (FLUKA, Geant3/4 …) codes produce different results
  - To be compared with measurements
- Sources of uncertainty:
  - Hadron production models…
  - Material models (inclusion of cooling circuits, etc.)
  - Proton beam modeling/measurements

NA61/SHINE

NA61/SHINE Neutrino Data Runs

Alysia Marino

Primary data collected for neutrino experiments to date

Additional TPCs added

Major detector upgrade

2007–2010

- 31 GeV/c p on thin C target
- 31 GeV/c p on T2K target

2015–2018

- Total cross section measurements
- 60–120 GeV/c p and π on thin C, Be, Al targets
- 120 GeV/c p on NOvA target

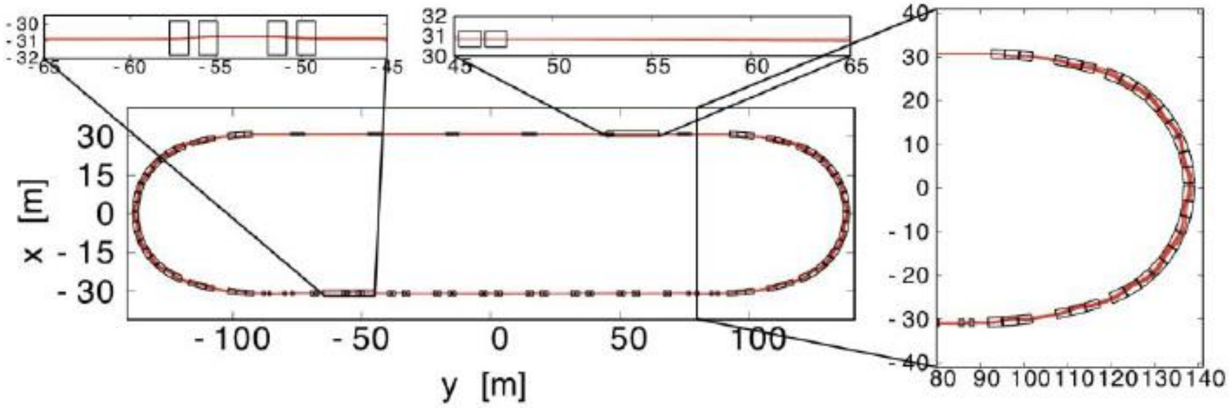
2022–2025

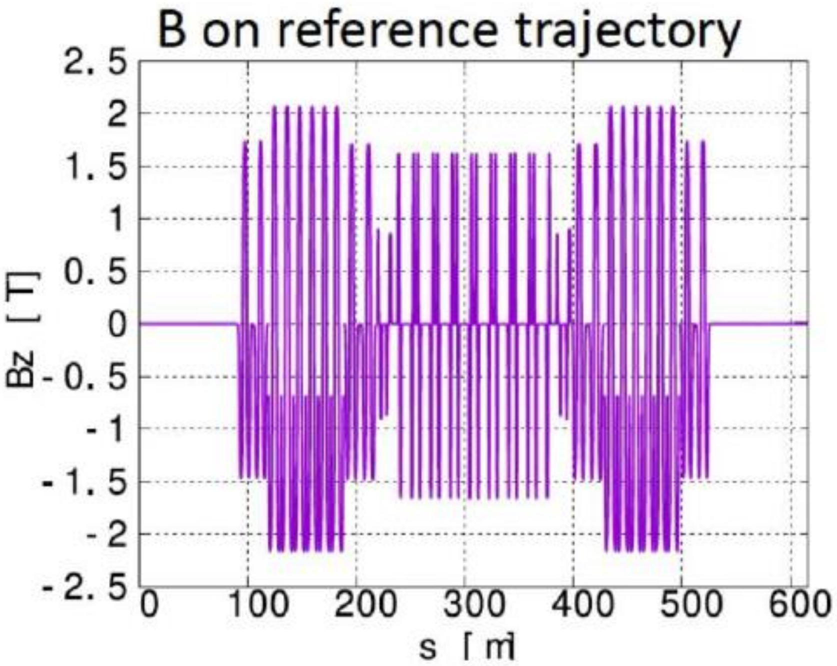
- 31 GeV/c p on T2K target
- 60 GeV/c K^+ on C target
- 120 GeV/c p on C and Ti targets
- 90 GeV/c p on C
- 120 GeV/c p on DUNE target

Marvin Pfaff

nuSTORM at CERN

- Optimized for 3.8 GeV/c muons from 5 GeV/c pions
  - Scaleable 1-6 GeV/c muons
- Low energy region challenging
- Hybrid lattice:
  - Standard focusing-defocusing quadrupole structure in production straight
  - Fixed-field alternating gradient lattice for the rest
  - Large energy acceptance (±16%)

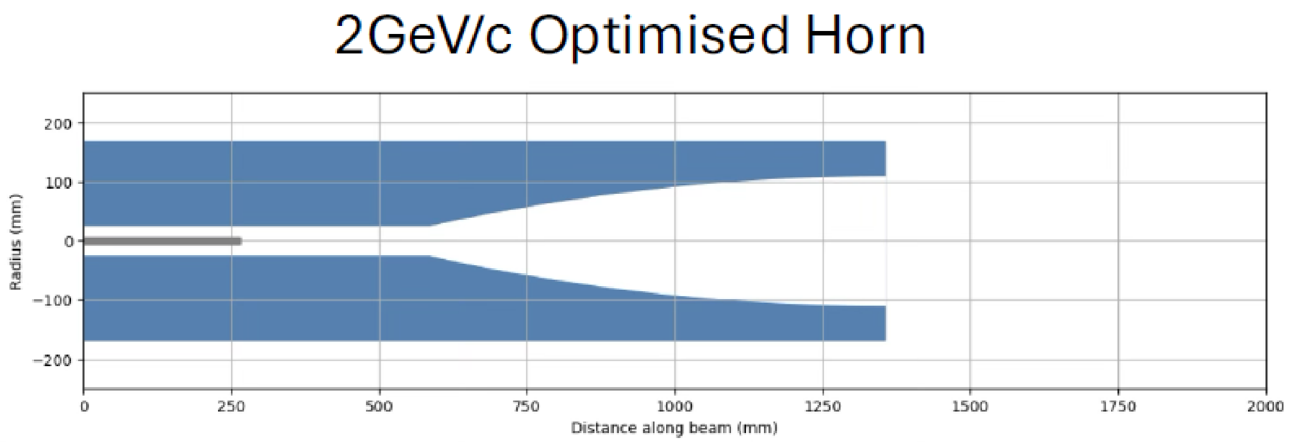


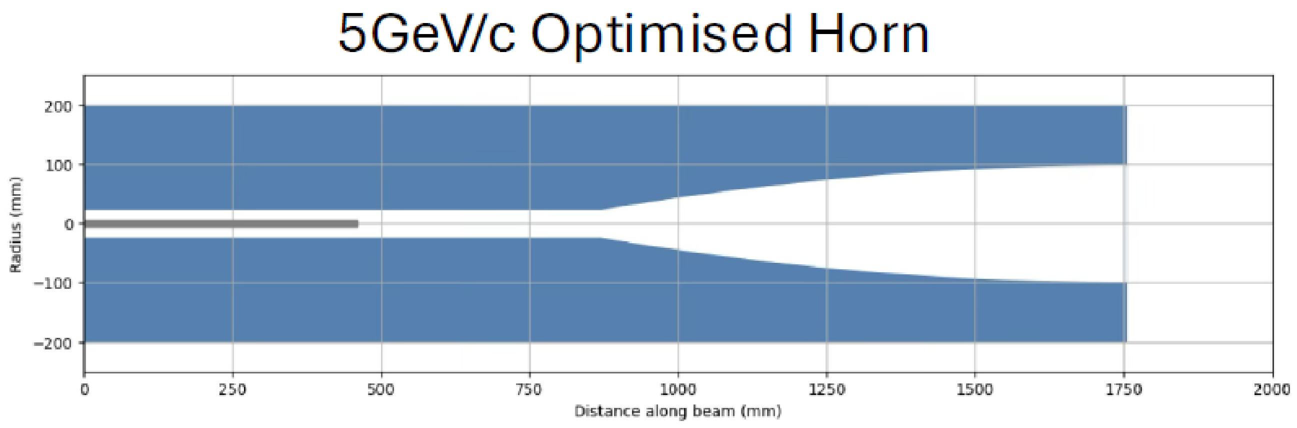


Re-optimization of the horn

Marvin Pfaff

- Bayesian optimization of horn to increase flux
  - 104% better for 2 GeV/c
  - 38% better for 5 GeV/c





Low-Energy nuSTORM at ESS

Max Topp-Mugglestone

Ting Wing Choi/Maja Olvegård

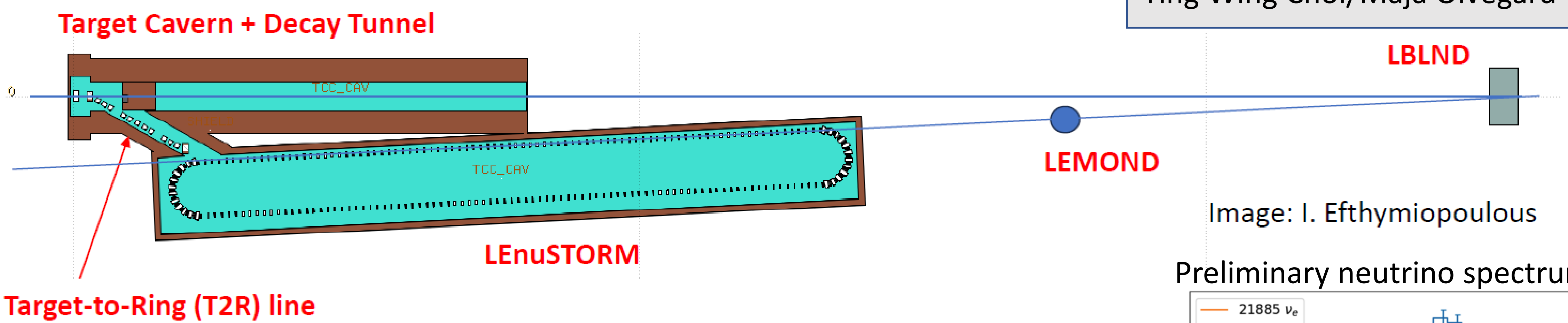
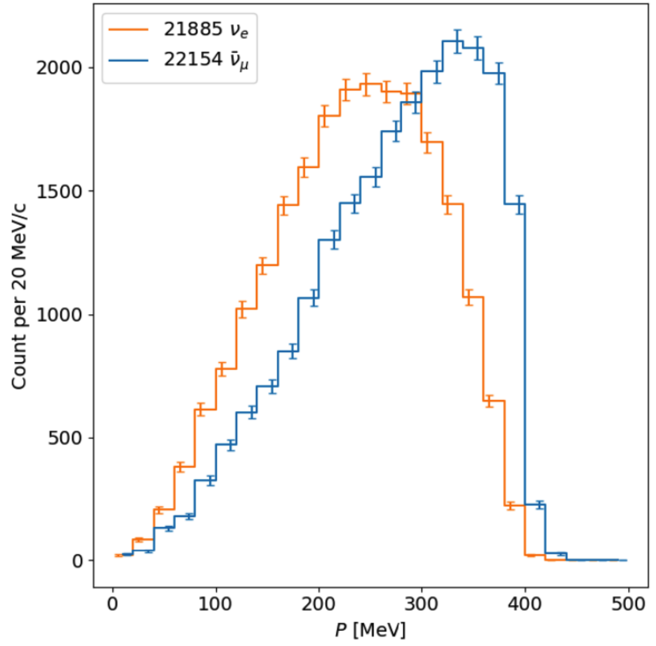


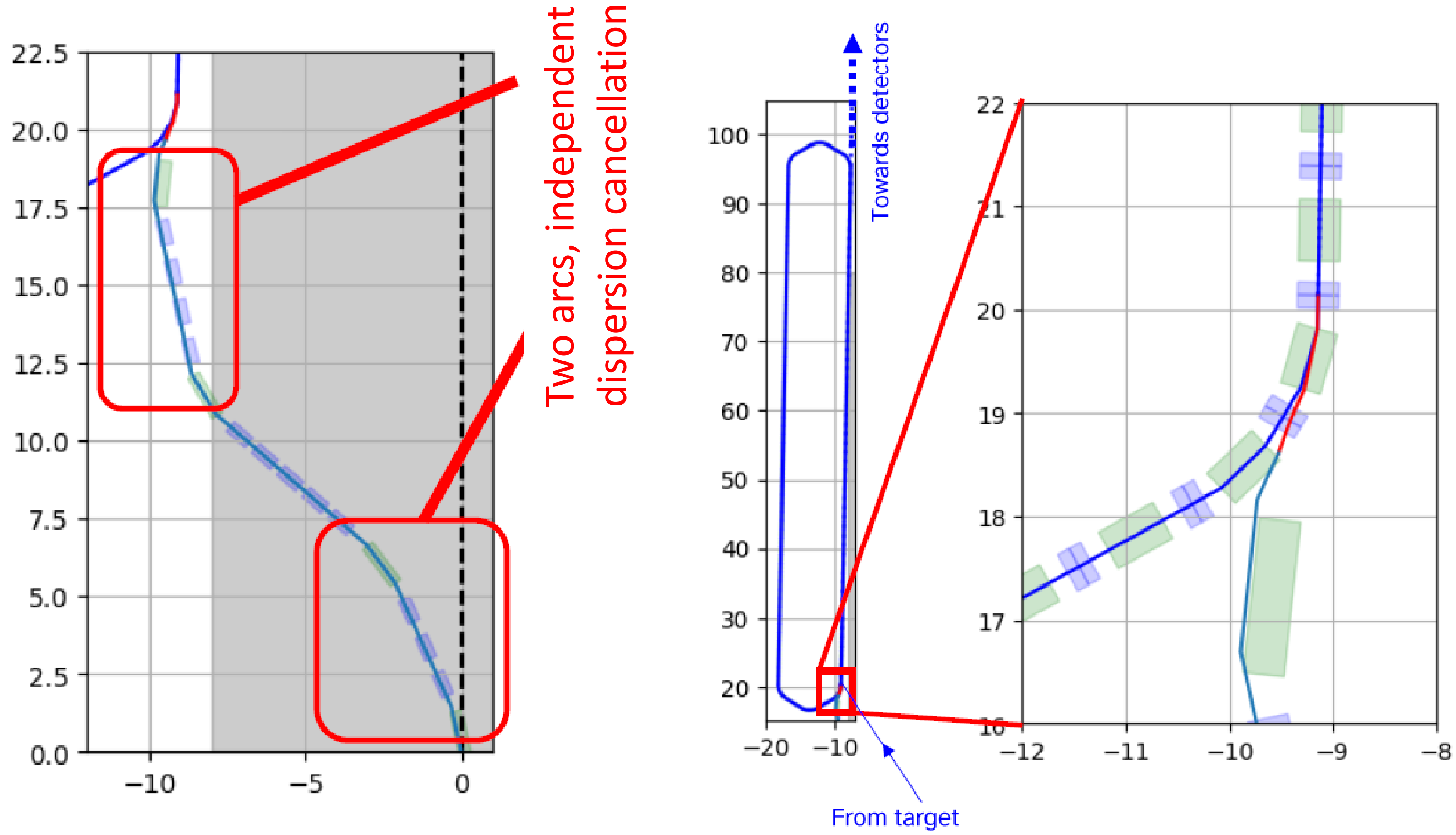
Image: I. Efthymiopoulous

Preliminary neutrino spectrum

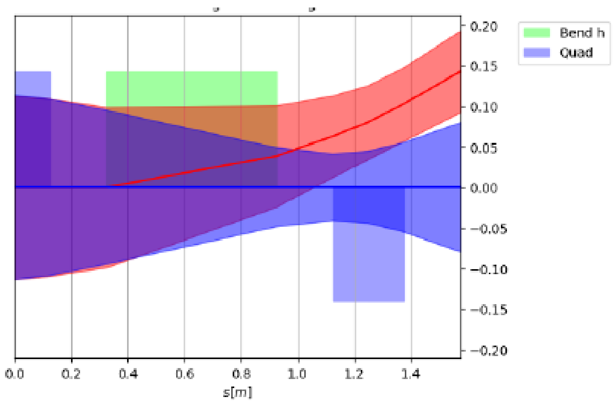


- 176 m long muon racetrack ring
- Normalconducting magnets, simple FODO structure
- To do: non-linear elements, corrections

Low-energy nuSTORM: pion transfer and injection



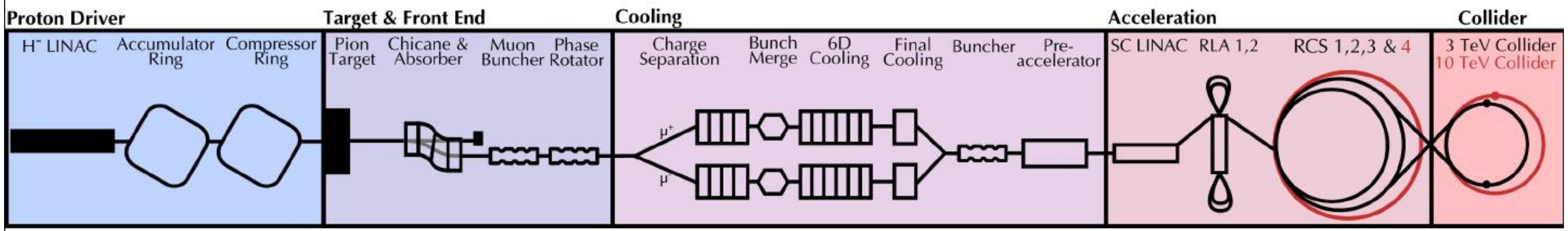
Max Topp-Mugglestone



Beam profiles assuming 3mm emittance, 10% momentum spread

Muon Collider

Chris Rogers

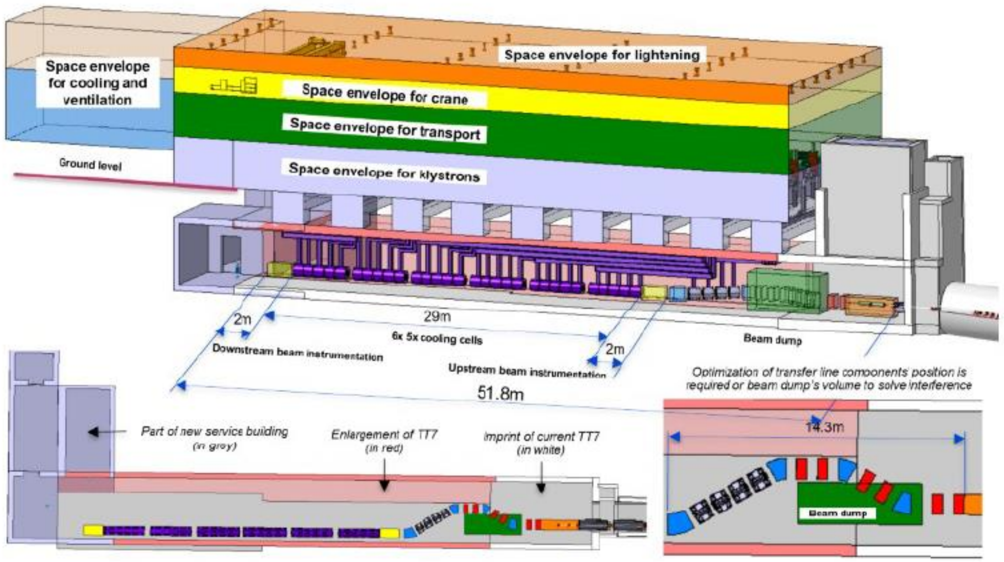


- The muon collider
  - Far higher energy than e^+e^- colliders
  - Far smaller footprint than equivalent proton colliders
  - More power efficient, more cost efficient
- Many technical challenges

- MW-class proton driver → target
- Pions produced; decay to muons
- Muon capture and cooling
- Acceleration to TeV & Collisions
- Designed for high energy while **maximising luminosity**
  - Luminosity is key

Demonstrator Implementation

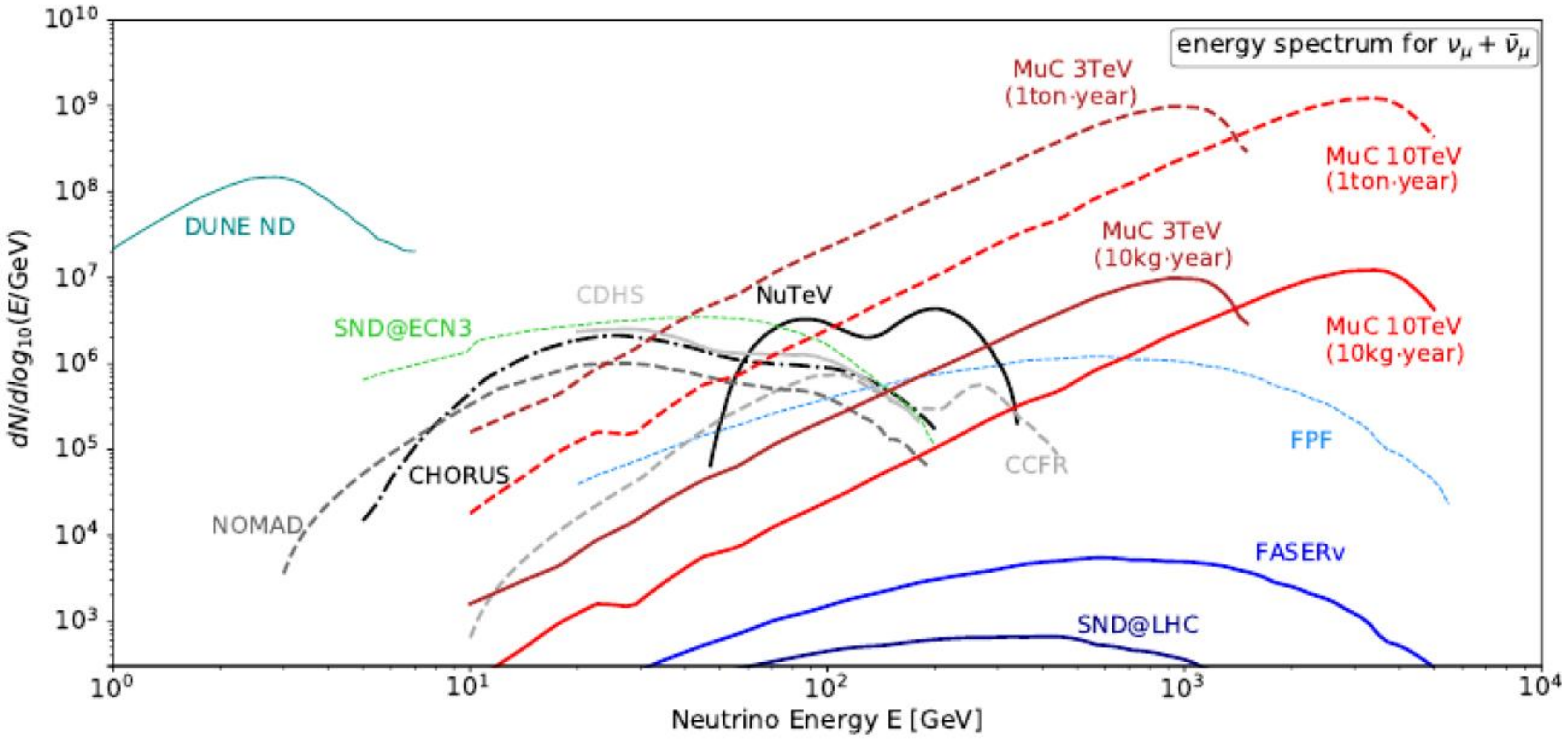
Chris Rogers



- Development of engineering model for cooling cell
- Integration and siting considerations for CERN or Fermilab

Lots of neutrinos

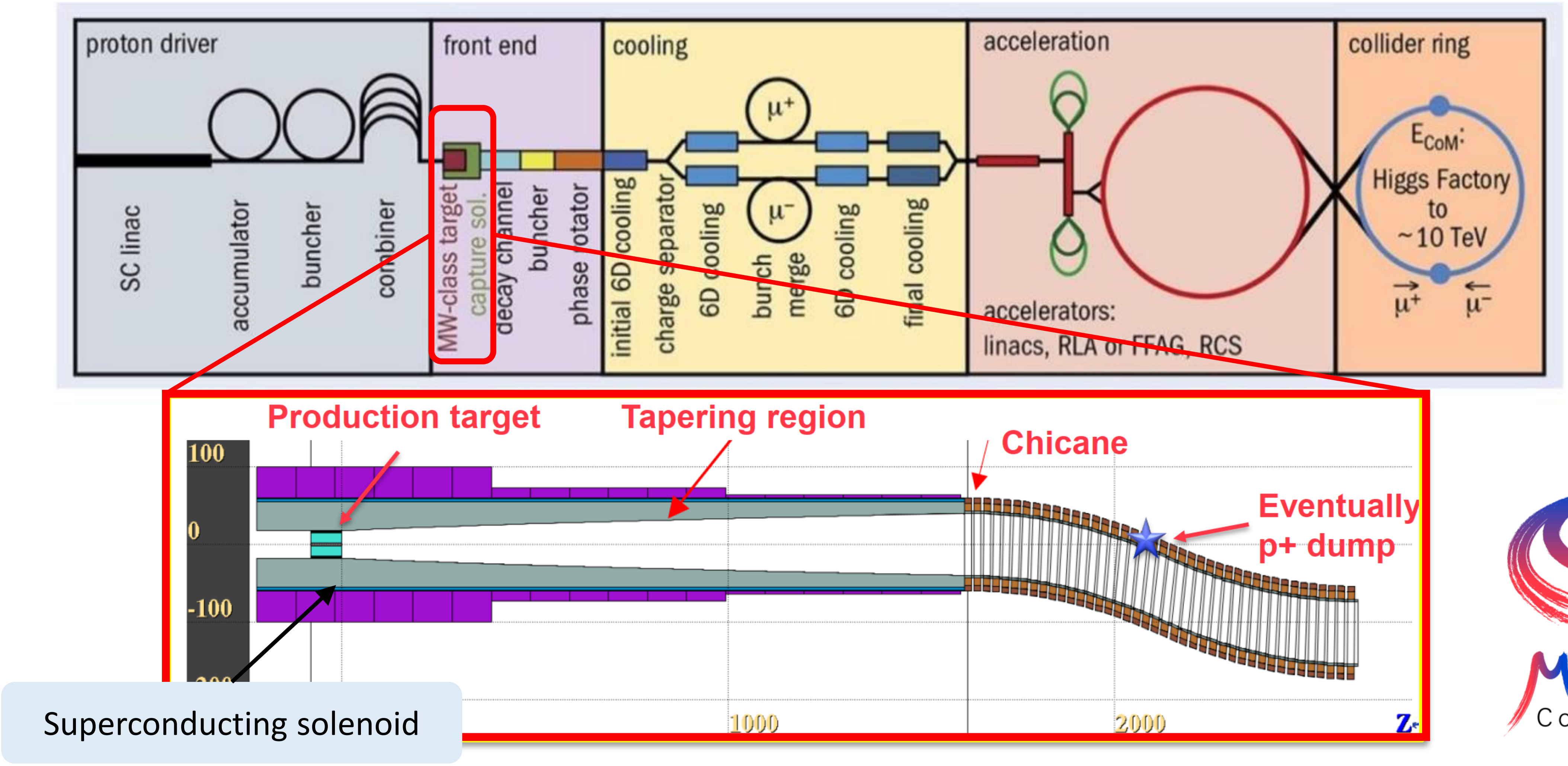
Chris Rogers



- Move beam or beam elements
- Neutrino detectors on land surface

Muon Collider: Target Development

Rui Franqueira Ximenes



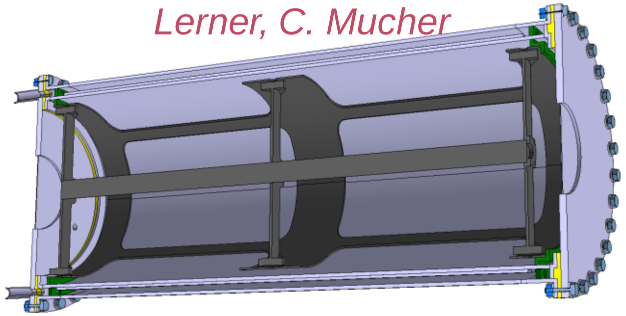
Muon Collider Targetry Options

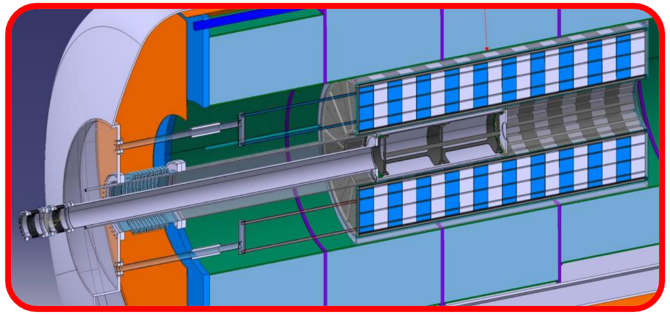
Rui Franqueira Ximenes

C-Target & target system

CERN

S. Cândido, R. F. Ximenes, M. Calviani, D. Calzolari, A. Lechner, F. Saura, J. Manczak, G. Lerner, C. Mucher

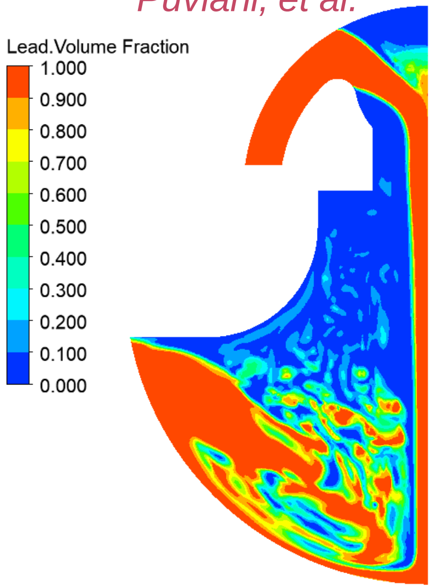




Liquid Pb Target

ENEA & CERN

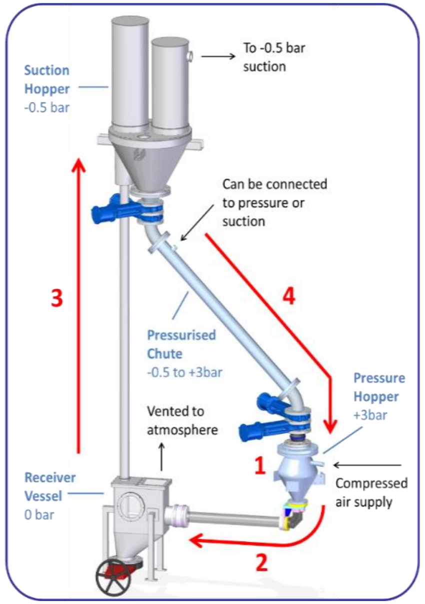
C. Carrelli, L. Tricarico, M. Tarantino, I.Di Piazza, P.C. Puviani, et al.



Fluidized W-Target

RAL & Warwick Uni.

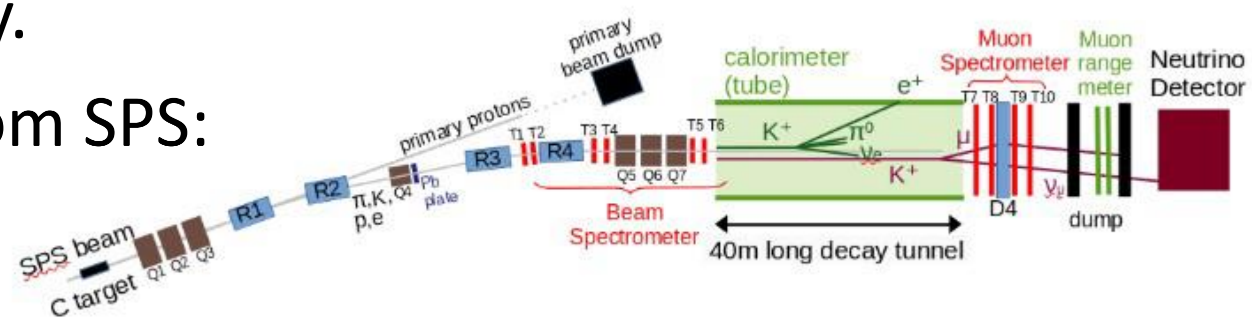
B. Suitters, C. Densham, J.J. Back, W. Bishop, D. Wilcox, et al.



NuTag + ENUBET = nuSCOPE

Marc Andre Jebramcik

- nuTAG and ENUBET: two proposals to fully monitor neutrino properties from pion/kaon decay.
- Two possible locations, beam from SPS:
  - North area
  - TT61/TNC region
    - Requires new scheme for slow extraction with non-local orbit distorsion
- Genetic algorithm to optimize particle yield:



@p=400 GeV/c

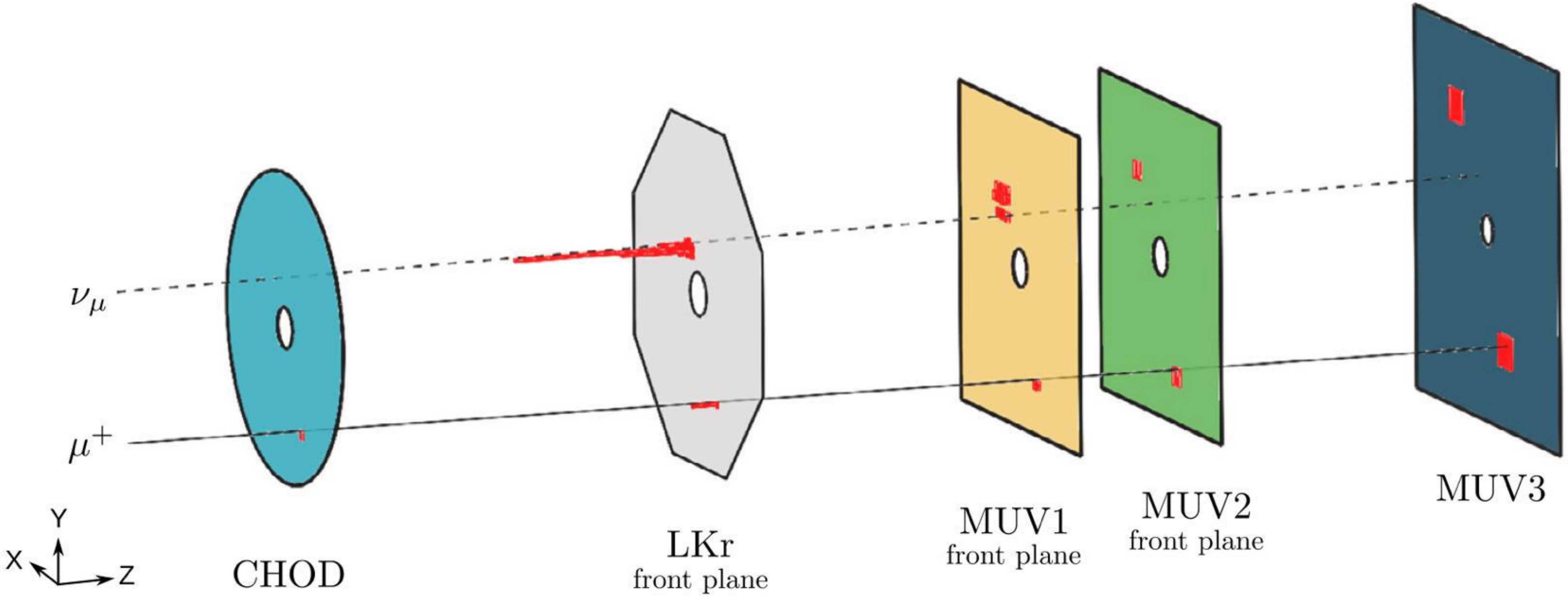
Particle yield	SPS: ENUBET design	SPS: Optimized beamline
K^+/PoT (10^{-4})	3.6	12.6
π^+/PoT (10^{-2})	0.4	1.9

Factor 3.5

Neutrino Tagging: NA62

Radoslav Marchevski

- First fully tagged neutrino candidate detected at NA62!



Concluding remarks

- Accelerators feed many neutrino physics experiments
- Higher neutrino flux
  - Increased proton beam power /number of protons on target
  - Improved target yield
  - Improved hadron focusing
  - ➢ Many challenges to tackle!

  …intensity limitations in proton beams, radiation in target and beamline environments, cooling, fatigue…

- Important synergies to benefit from (short and long baseline, muon collider, neutron spallation, a.s.o.)

Thank you for all the interesting talks and inspiring discussions!