WG3 Summary: Accelerator Physics

NuFact 2023, Seoul

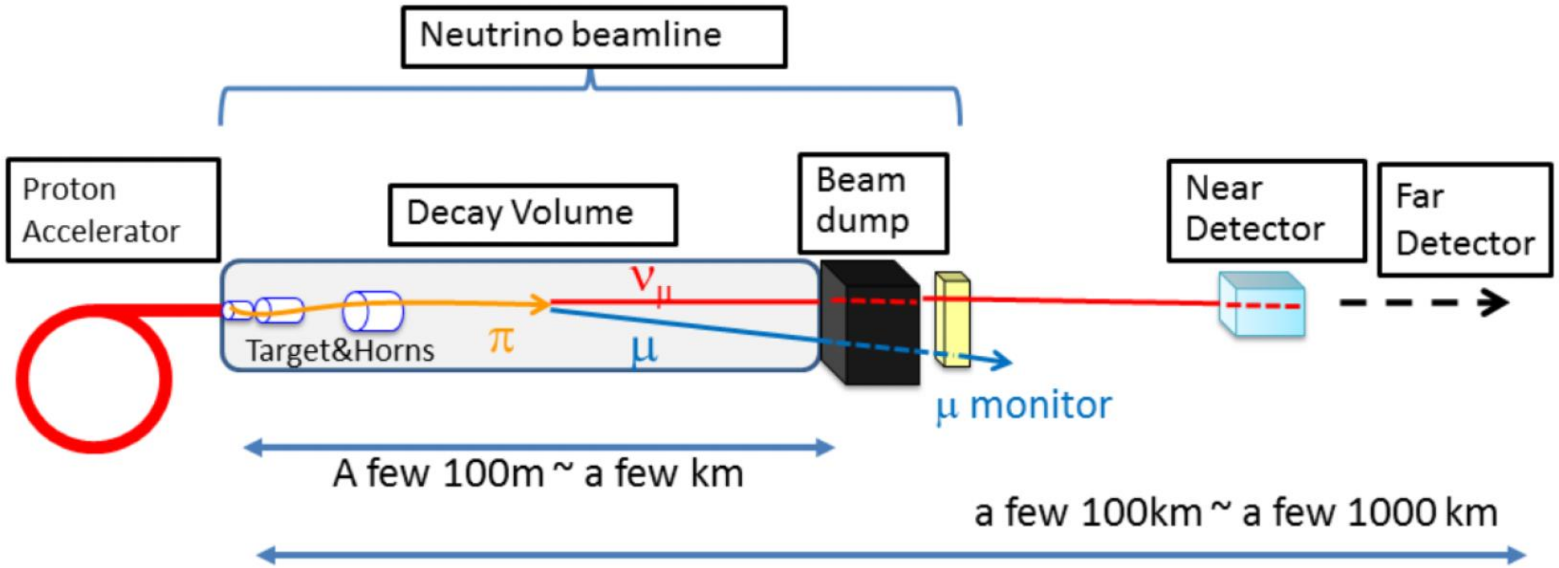
MEGAN FRIEND (J-PARC)
KATSUYA YONEHARA (FERMILAB)
NATALIA MILAS (ESS)

WG3 talks

A bit of statistics

- Plenary session
  - 3 plenary talks and
  - 1 plenary shared with WG4
- 3 parallel sessions (13 talks)
- 1 WG3X4 joint parallel session (5 talks)
- 1 WG3X1 joint parallel session (5 talks)

Accelerators for Neutrino Experiments

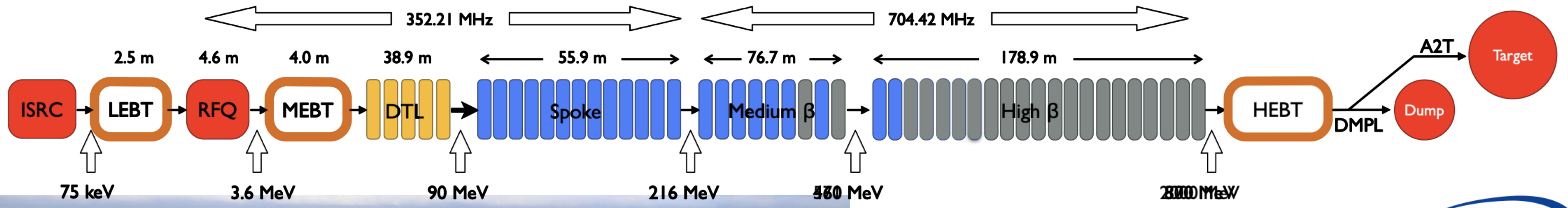


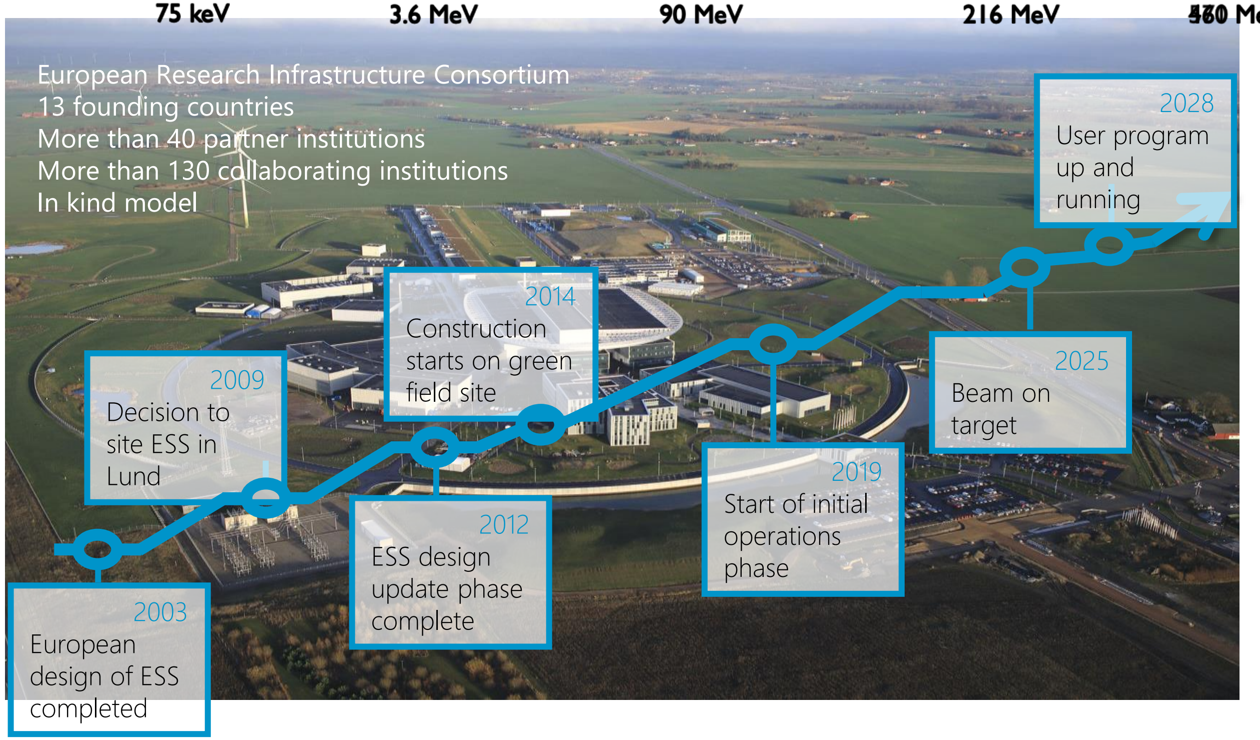
- Conventional current and near-future world-class neutrino beams require:
  - High-intensity proton beam
    - Manipulation of high-power beam
    - Commissioning towards stable operation
  - Radiation-hard equipment
    - Targetry, monitoring
  - Proper understanding of beamline/modeling
  - Synergies between neutrino and muon beamlines

The era of Multi-MW facilities is here

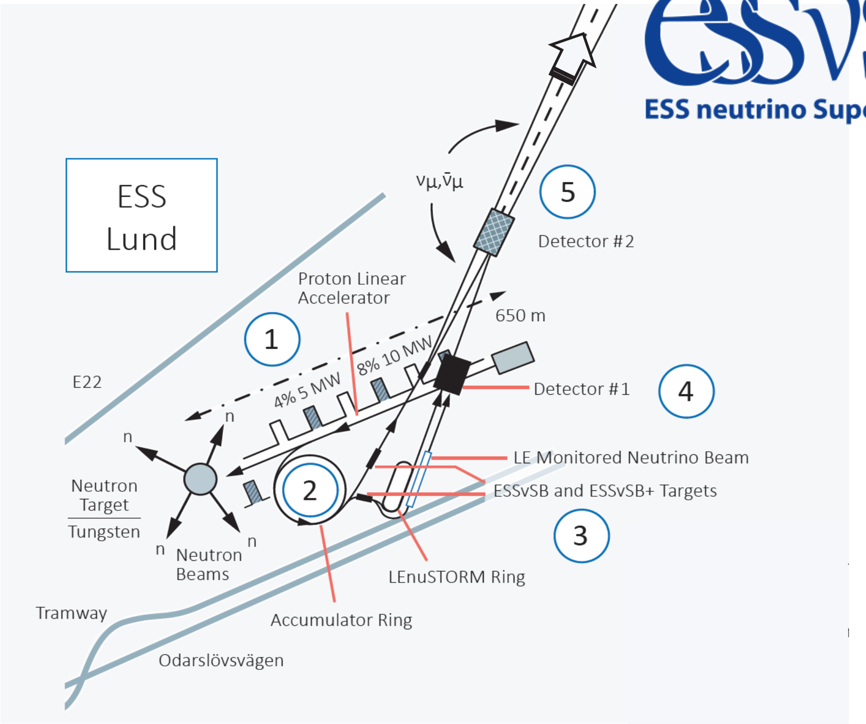
A. Jansson

High intensity proton beams





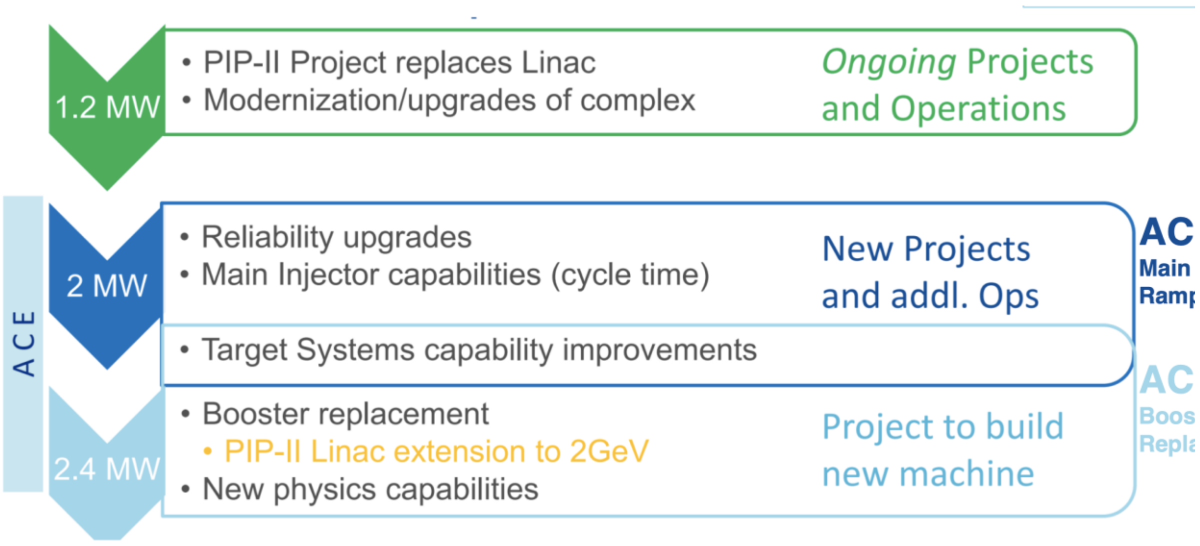
ESS neutrino Super Beam plus



J. Eldred

The era of Multi-MW facilities is here

High intensity proton beams



2.4 MW Upgrade with Reliability, Capability, Capacity

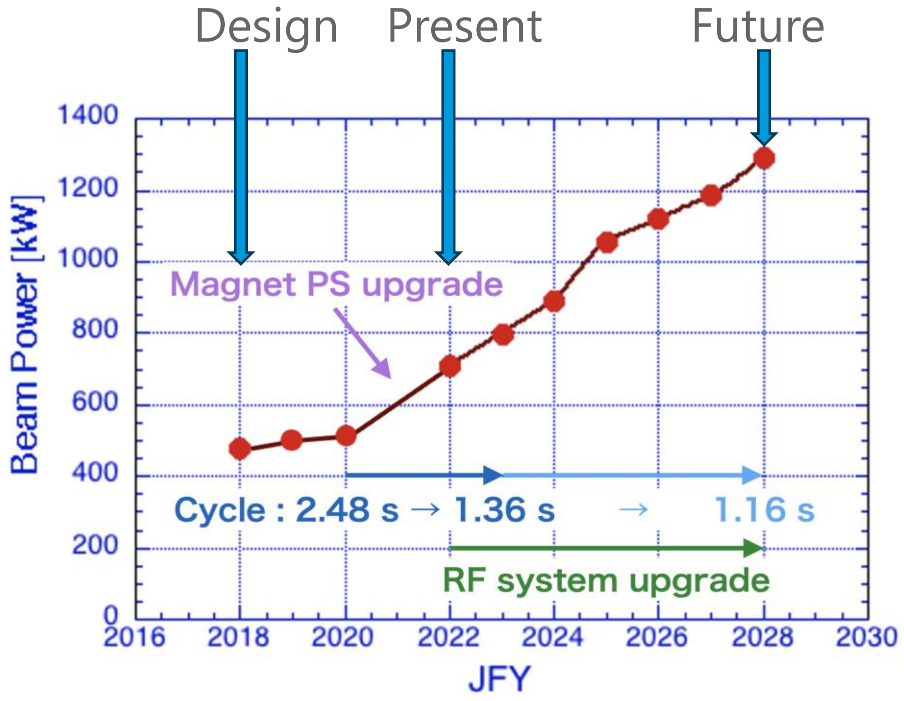
With increasing power:

- Replace and upgrade accelerator components
- Beam dynamics/studies
- Target upgrade plan
- Horns for high power beams

The era of Multi-MW facilities is here

T. Nakadaira
T. Yasui

High intensity proton beams



Plans for far future:

- Add a Booster ring: 3-5 MW
- Re-use the Super-KEKB tunnel: 9 MW

Upgrades:

Magnet power supplies

- Stable 1.36 s cycle ramping pattern was established.
- Ripple suppression and studies for 1.16 s cycle are ongoing.

RF system

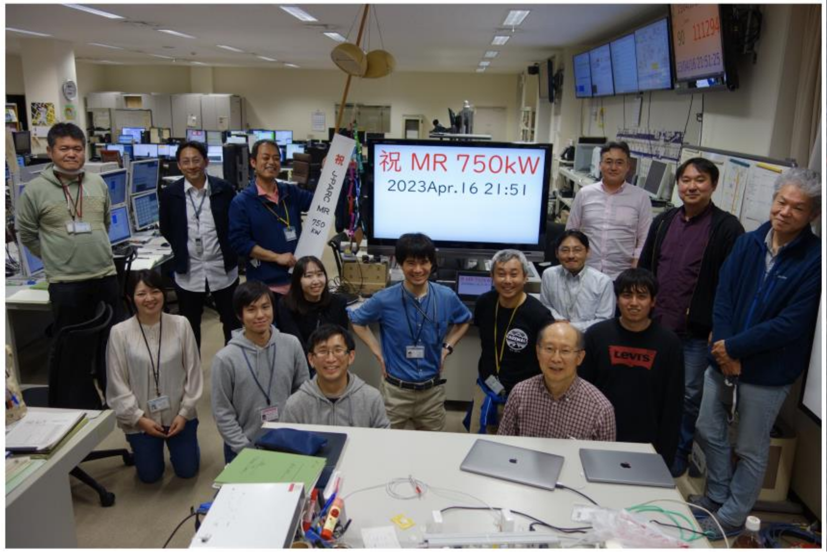
- RF cavities and anode power supplies will be upgraded.

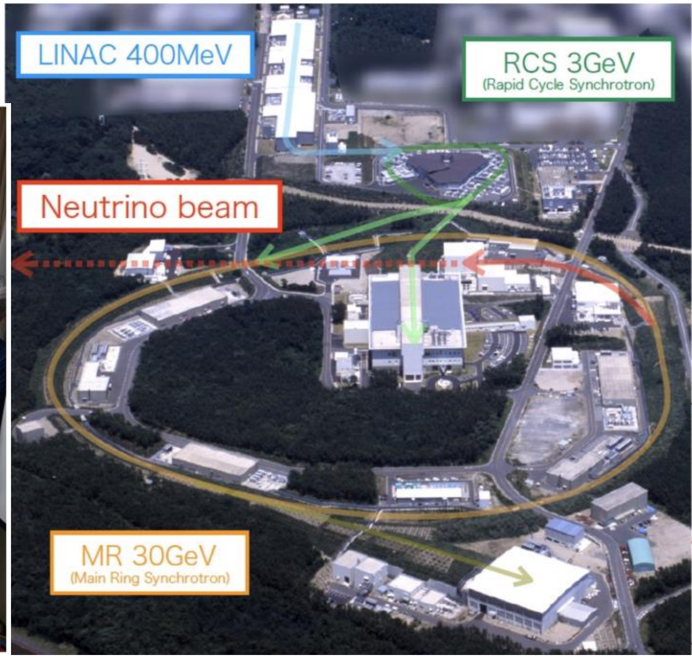
Injection/Extraction system

- All the FX septum magnets were replaced.

Collimator system

- The number of the collimators was increased.

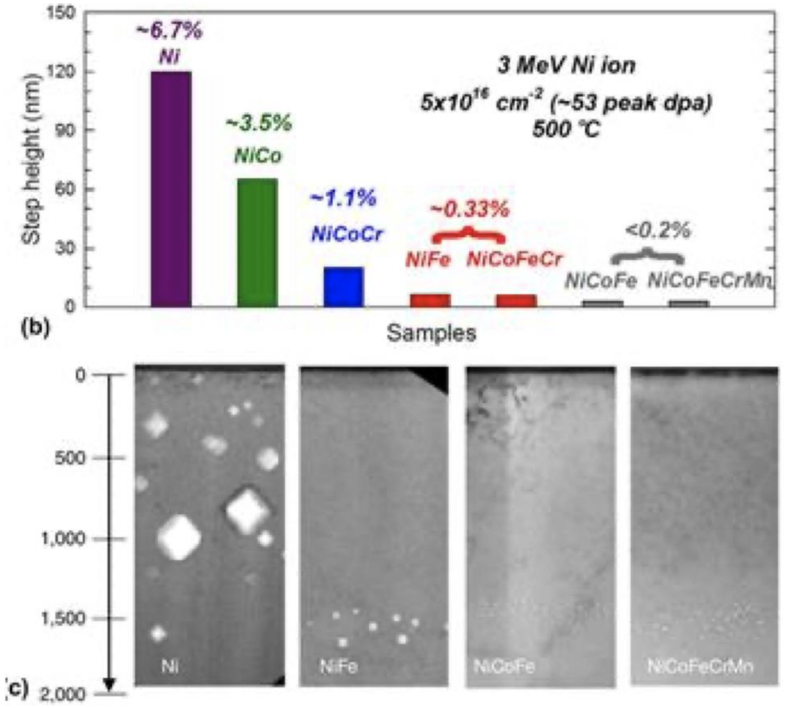


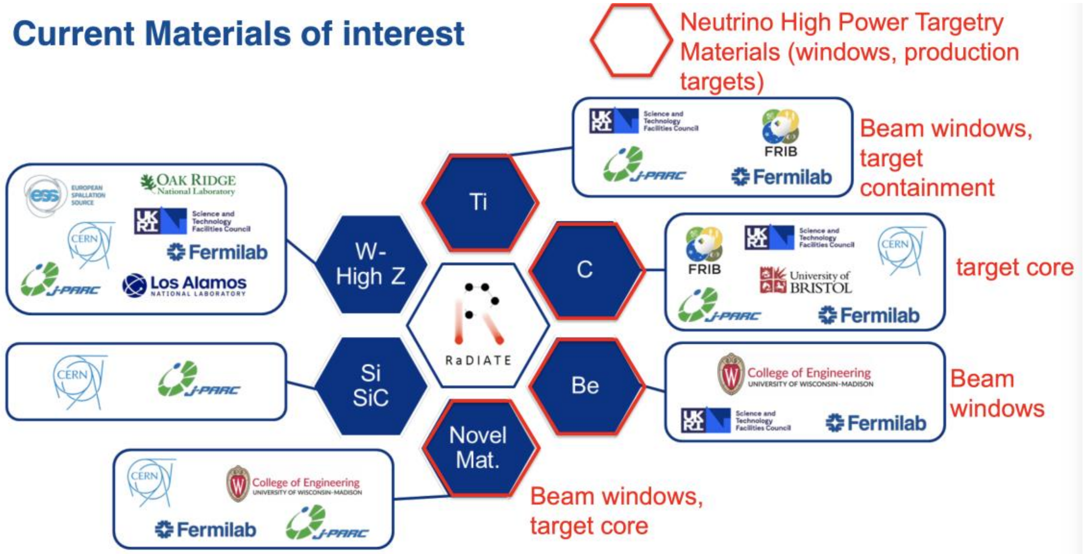


Target Materials

Radiation hard equipment

Radiation tolerant property of HEAs





2.4 MW target will require significant R&D to guide design and material choice

Understanding material behavior under intense multi-MW beams is high priority :

- Radiation damage effects from lattice disruptions and gas transmutations
- Beam-induced thermal shock limit of materials
- Needs to focus on fatigue study for irradiated materials

G. Arora

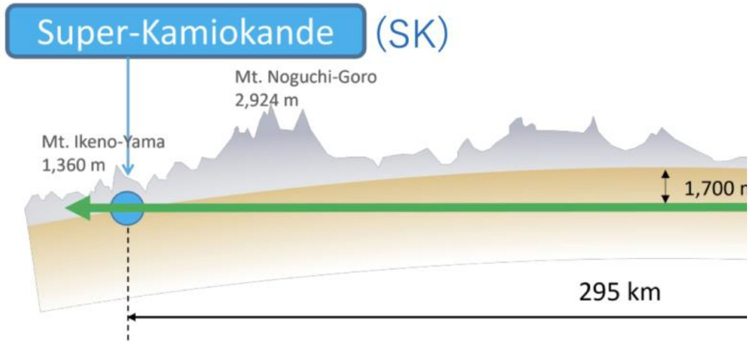
Diagnostics

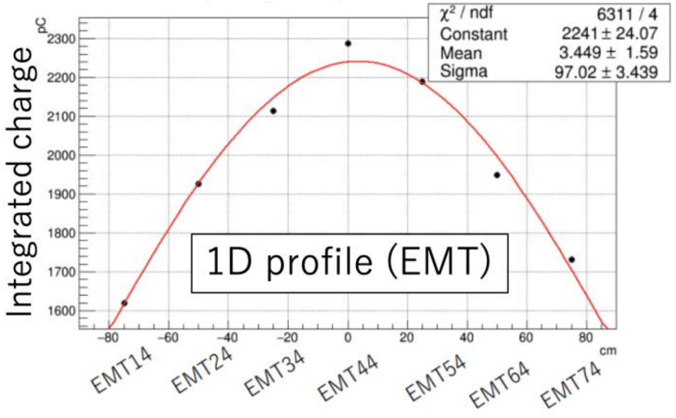
Understanding of beamlines

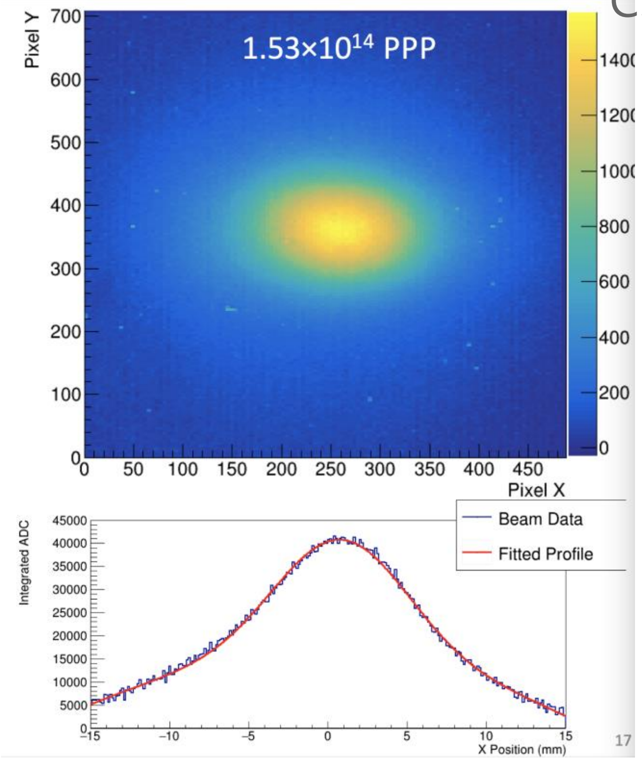
Y. Sato

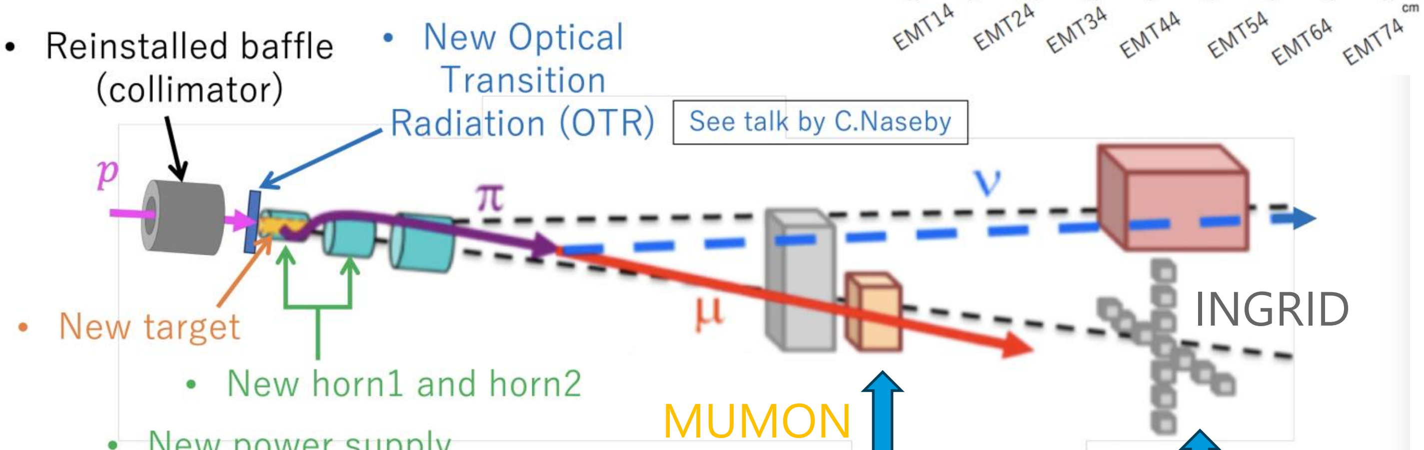
MUMON
New EMT (Electron Mult. Tube)
Better radiation tolerance

C. Naseby









- Checked the beamline component alignment using proton and muon monitors during ~2 days of beam commissioning
- Measured the neutrino beam position and width during ~26 hours of continuous running

10

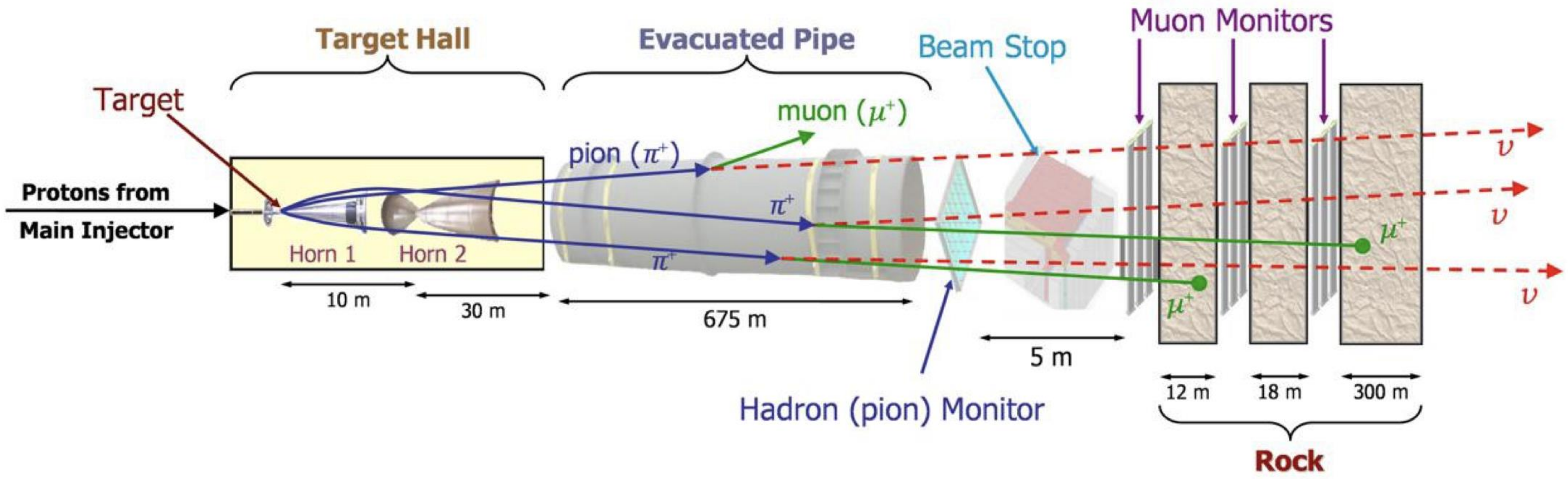
OTR: closer to target significantly improve position accuracy.
Upgrades:

- Mechanical: OTR wheel, limit switch and harder flange (wear)
- New camera taper (rad. damage) and DAQ
- Issues: fluorescence (He) and background

Diagnostics

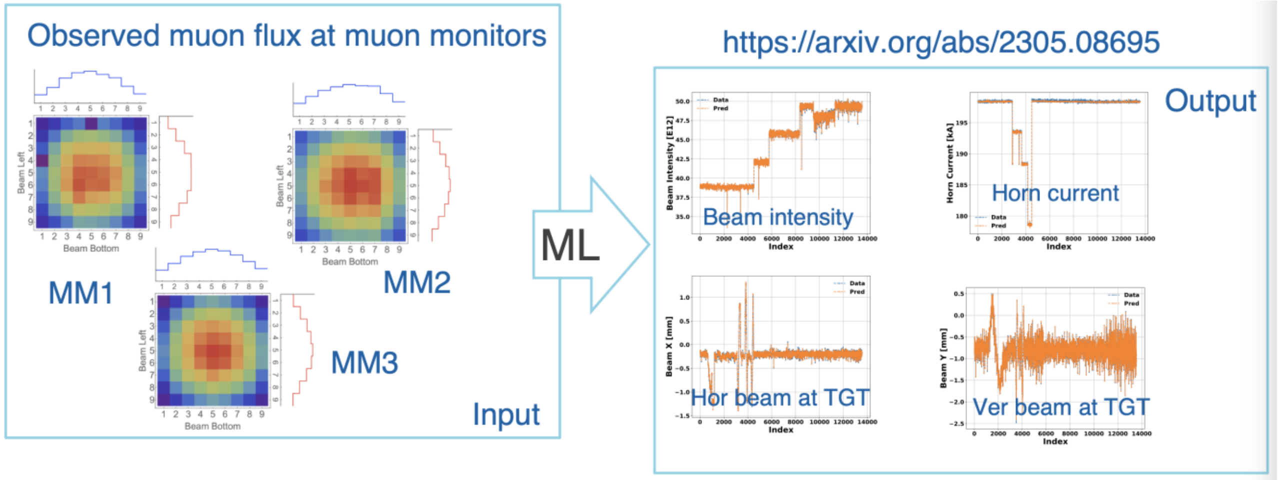
K. Yonehara

Understanding of beamlines



Observed muon flux tells us the condition of target system by comparing with heavy volume MC simulations

- Beam position on target in transverse plane (x and y)
- Beam spot size on target in transverse plane
- Horn current



Applications:

1. NUMI beam position scans
2. Beam spot size studies
3. LBNF simulation

Apply muon monitors to detect the target anomaly!

Neutrino Flux Uncertainty

Understanding of beamlines

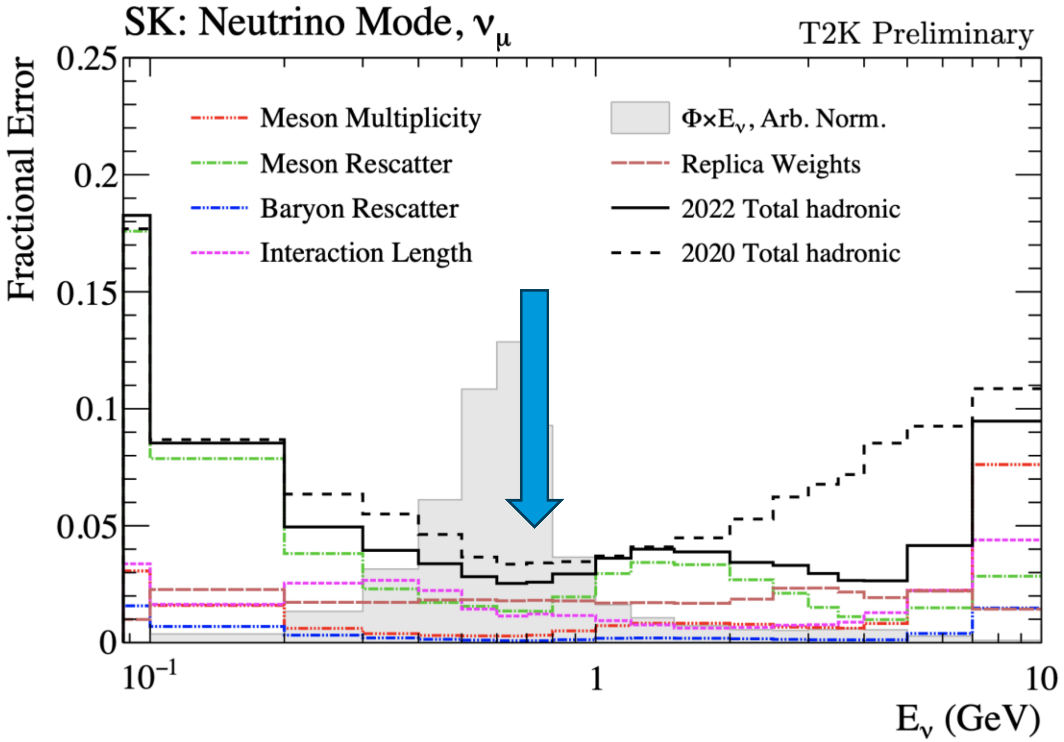
D. Cherdack

T2K flux prediction and tuning

M. Friend

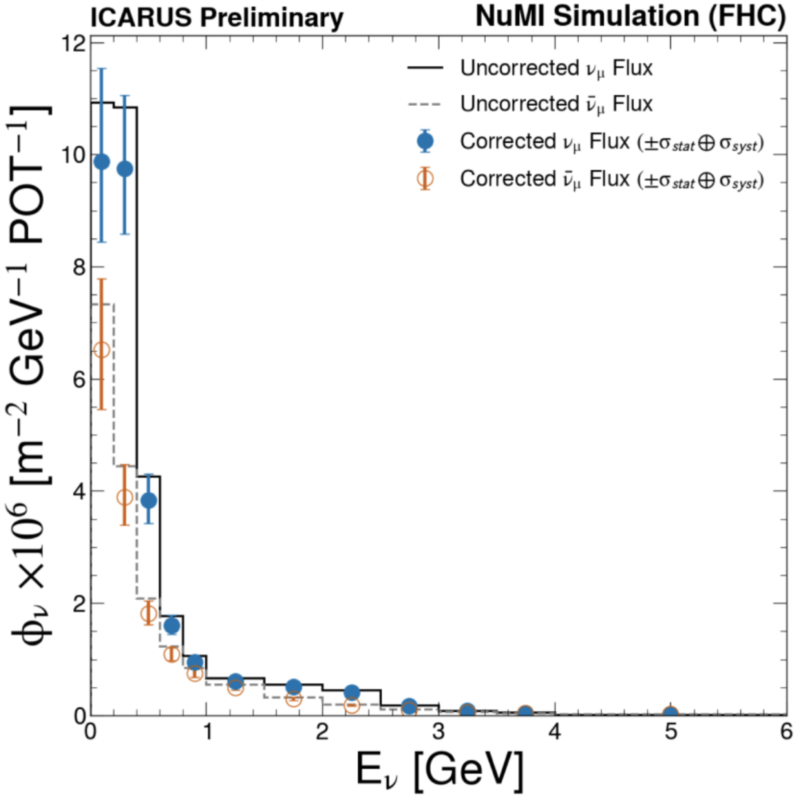
Additional external experiments to constrain hadron production are essential for reducing flux uncertainties. (NA61/SHINE and EMPHATIC)

Improved implementation of material in beamline (horn cooling water)



The NuMI Flux at ICARUS

Also looking to understand hadron production and also possibility for cross sections in Ar (1-3 GeV).



Neutrino Flux Uncertainty

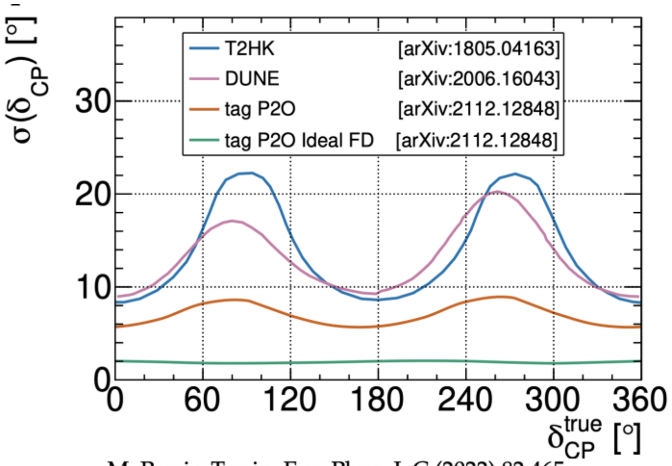
Understanding of beamlines

J. Bian

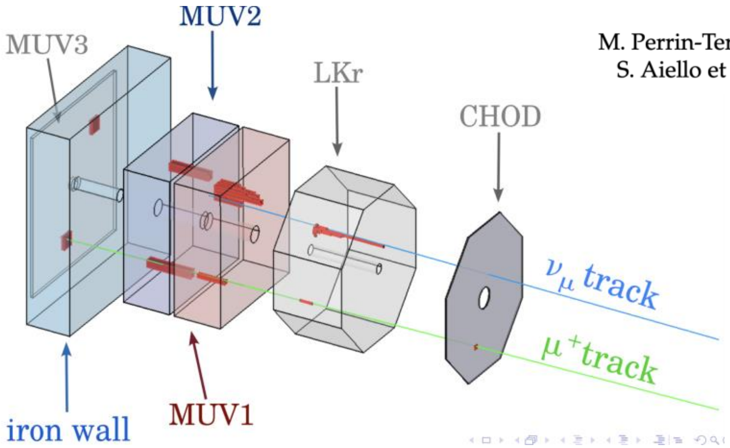
B. De Martino

Tagging technique at NA62

Short baseline (precise flux, refine interaction models)
LBLE (measure CP violation with unprecedent precision)

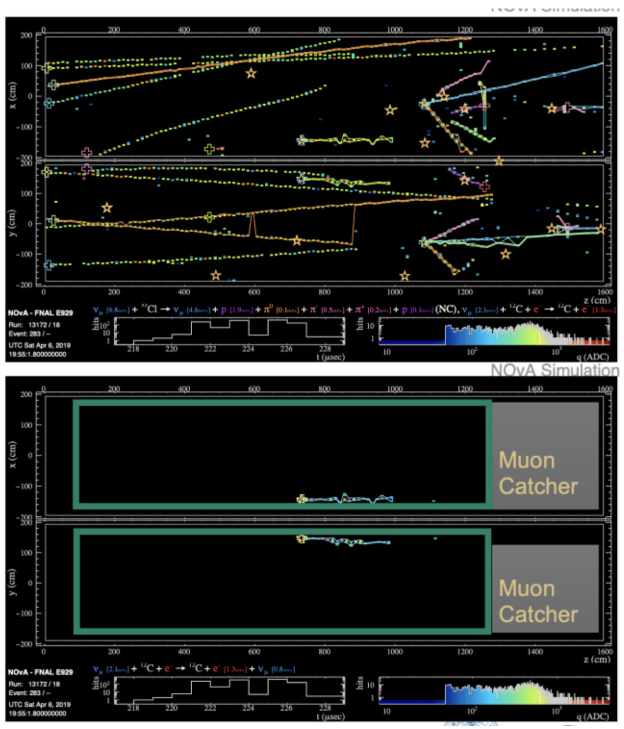


M. Perrin-Terrin, Eur. Phys. J. C (2022) 82:465
S. Aiello et al, Eur. Phys. J. C 82, 26 (2022)



Neutrino-electron Elastic Scattering at the NOvA ND

Large uncertainties on hadron production and neutrino flux. CNN-based classifier for event selection and a series of other studies -> reduction of flux uncertainty from 10 to 6%



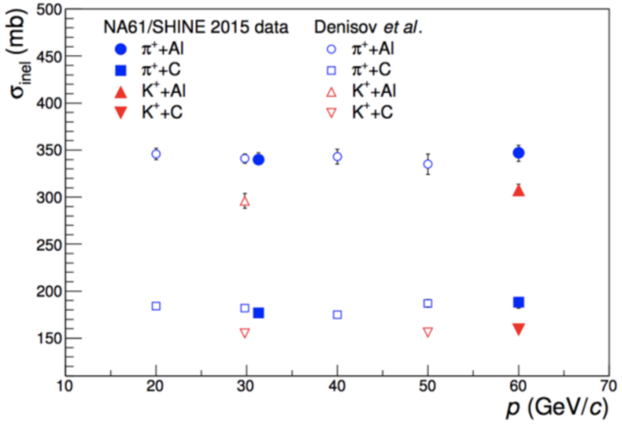
Neutrino Flux Uncertainty

Understanding of beamlines

NA61/SHINE experiment

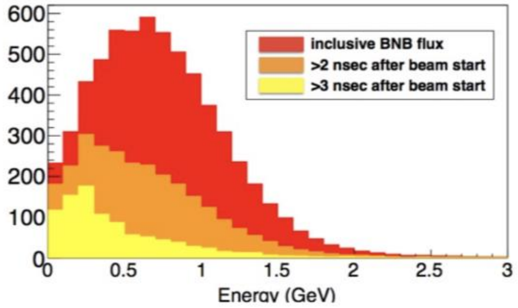
Y. Koshio

Recent measurements of pion and kaon inelastic interaction cross sections in carbon and aluminum thin targets to improve the knowledge of the neutrino flux.
Thin target behaviour vs thick target behaviour



Time slicing of Neutrino Fluxes

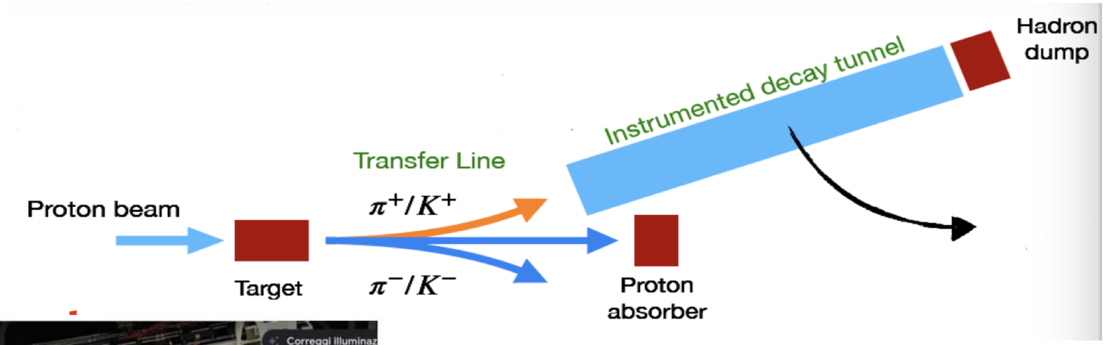
M. Bhattacharya

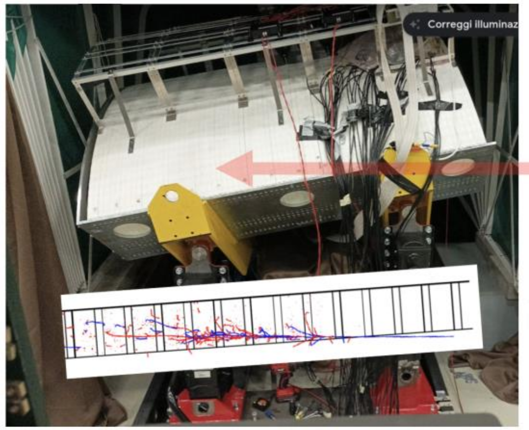


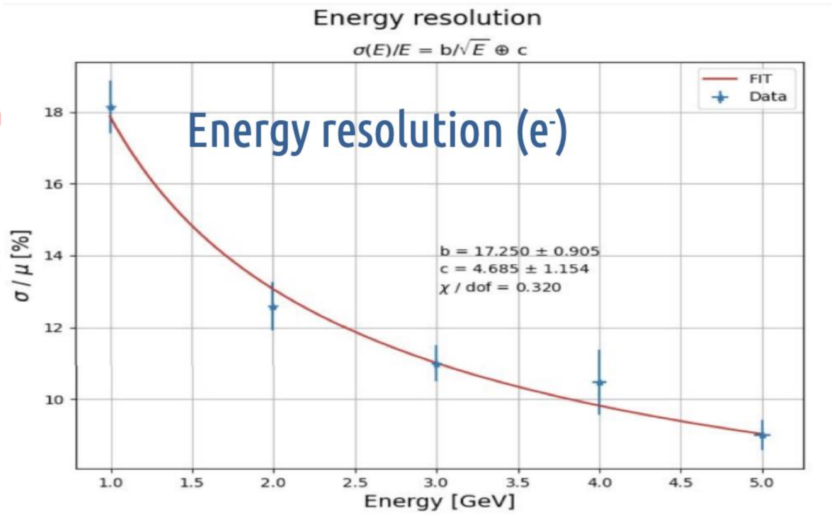
ENUBET

A. Longhin

Dedicated short baseline experiment to measure ν_e and ν_μ fluxes with 1% precision







Muon Beans

New Physics beyond SM

A. Sato

Beyond the SM

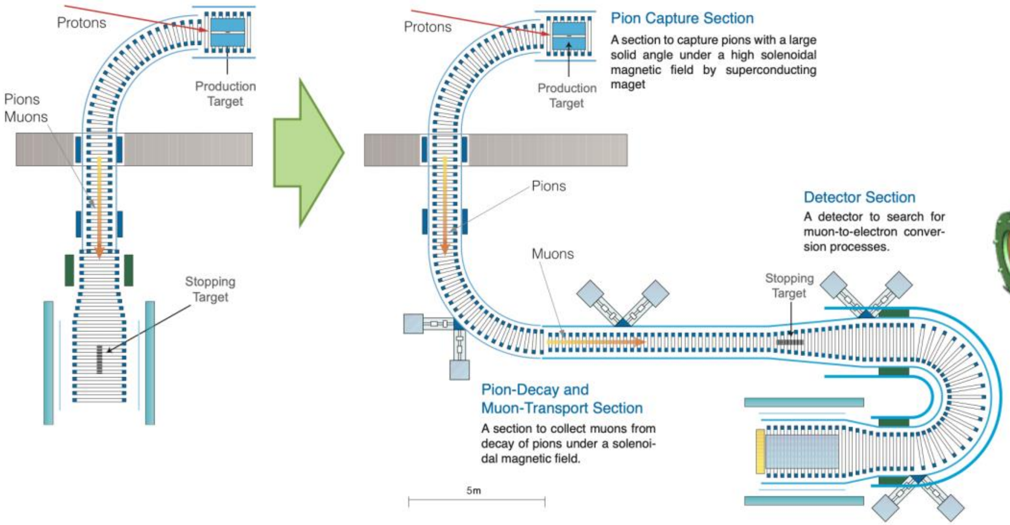
μ-e conversion

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

Forbidden by the SM, because
the lepton flavor is changed to μ-flavor to e-flavor.

Event signature :
a single mono-energetic electron of 105MeV (for Al)

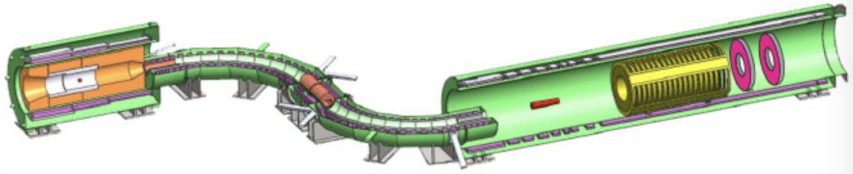
COMET @J-PARC



COMET Phase-I : S.E.S. ~ 3 x 10^{-15} on Al — Under construction

COMET Phase-II : S.E.S. ~ 3 x 10^{-17} on Al — Planed

Mu2e @FNAL



Mu2e: S.E.S. ~ 3 x 10^{-17} on Al — Under construction

Mu2e-II: S.E.S. **~ 3 x 10^{-18}** on Al — Under discussion

Features of the Setup

- Solenoid channel
- Stop μ^- at the stopping targets.

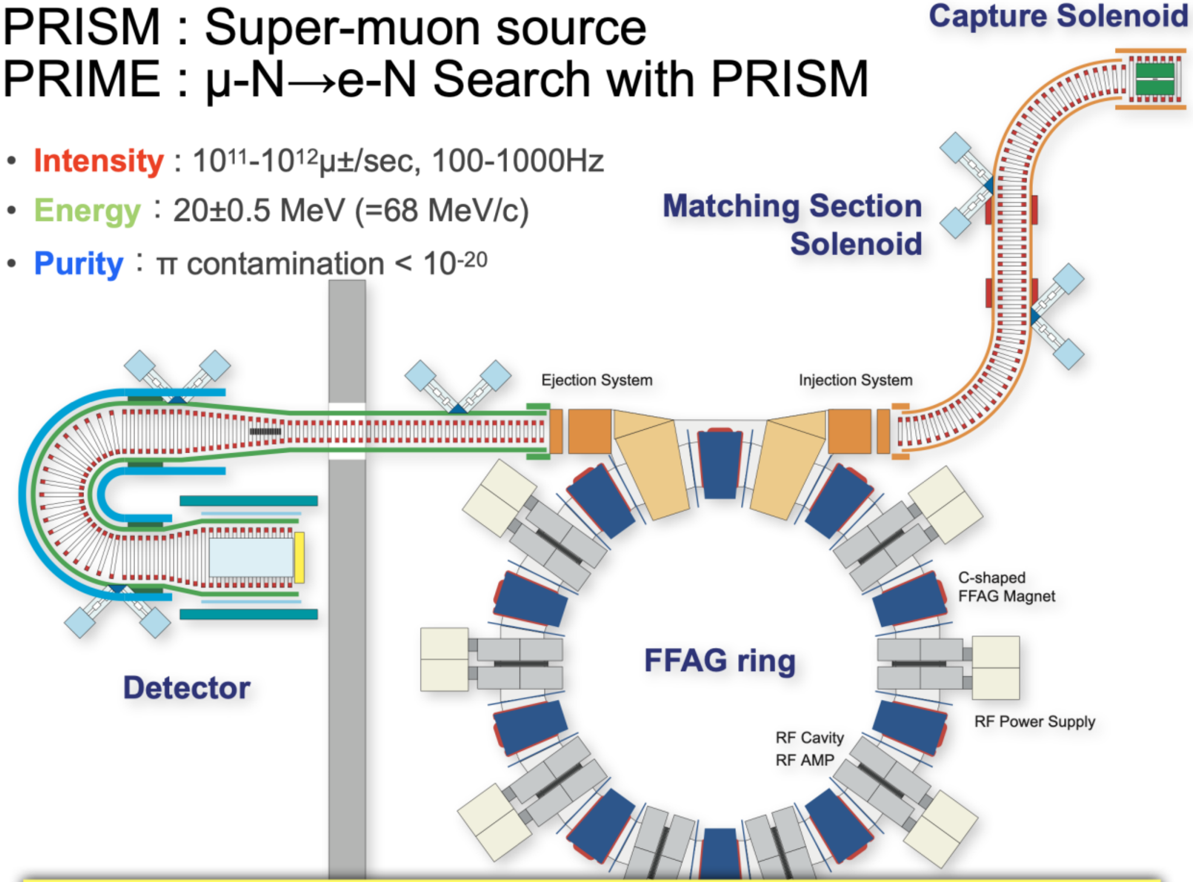
Muon Beans

New Physics beyond SM

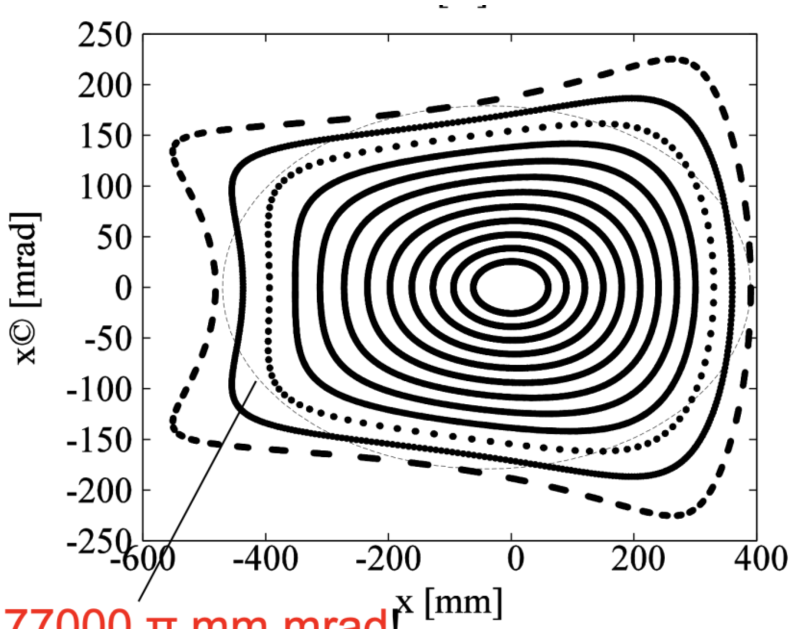
J. Pasternak

PRISM : Super-muon source
PRIME : μ-N→e-N Search with PRISM

- **Intensity** : 10^{11}-10^{12} μ±/sec, 100-1000Hz
- **Energy** : 20±0.5 MeV (=68 MeV/c)
- **Purity** : π contamination < 10^{-20}



PRISM-FFAG is a key device to achieve the mono-energetic and pure muon beam. Phase rotation is applied in the ring.



77000 π.mm.mrad!

- Real challenges for accelerator design.
- Optimization of the current FFA design is ongoing and is promising.
- PRISM has the potential to solve various difficulties in future experiments.
- Proton beam for PRISM can be generated at FNAL (using future power upgrade options) or at J-PARC

Muon Beams

N. Vassilopoulos

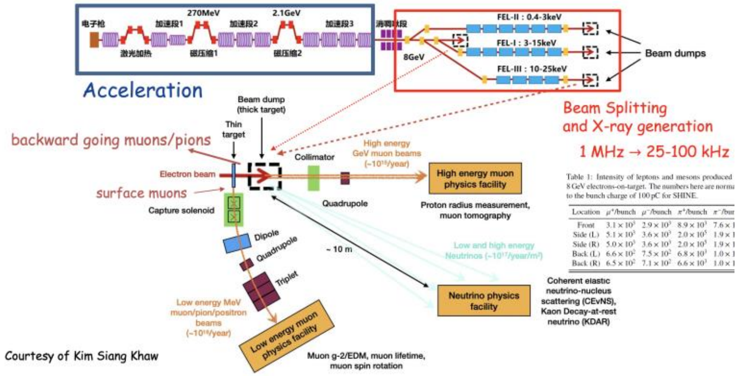
Surface Muons

MELODY at CSNS

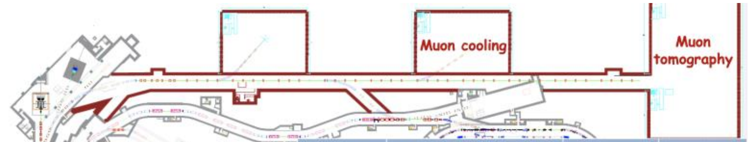
- *MELODY has been approved and funded for the μSR beam*
- Muon production target will be a rotated slab of graphite or copper
- Target and beam are optimized by AI
- Now: μSR and technology R&D beamlines
- Future: Decay and negative muons, the latter for muon-induced X-ray experiments

Other proposal for Muon Beams in China

Shine - Shanghai

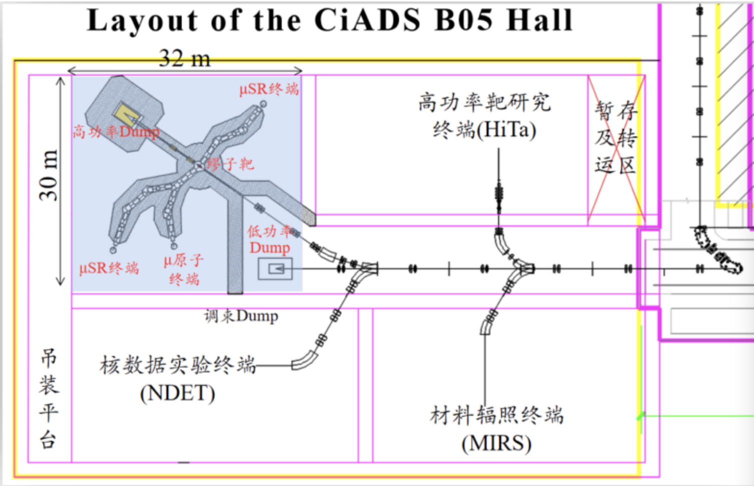


IMP - HIAF



Selection momentum (GeV/c)	Muon rate		Momentum	spread (σ)
	(ppp)	(ppp/cm^2)	GeV/c	MeV/c
1	2.99e+5	9.52e+2	0.99	21.69
2	2.01e+6	6.38e+3	1.96	43.87
3	1.9e+6	6.04e+3	2.90	85.9
4	3.35e+5	1.07e+3	3.90	87.42

IMP - CiADS



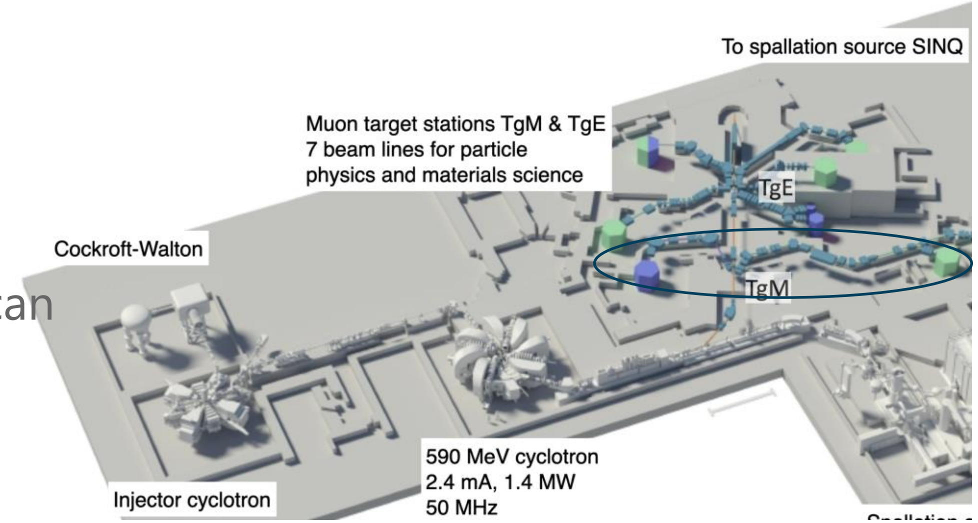
Muon Beans

G. Dal Maso

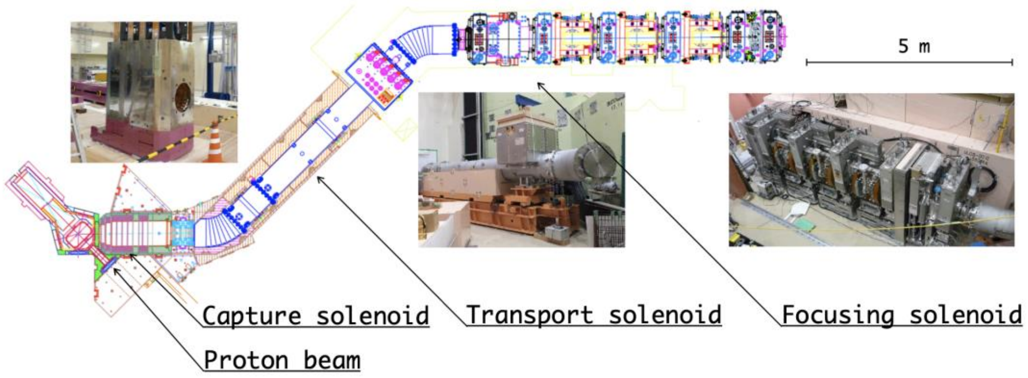
Surface Muons

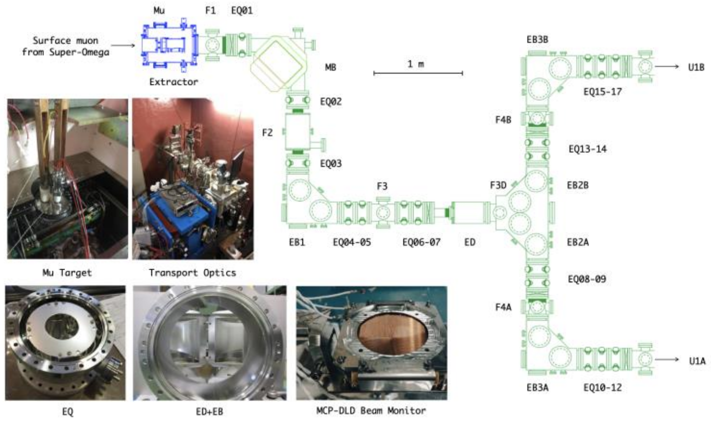
- Planned target M modification (higher intensity)
- Optimization of current beamlines
- Two new high intensity solenoid-based muon beamlines at 90 deg angle w.r.t. the proton beam. The solenoids along the beamlines will not be radiation hard, and the magnetic fields can be higher than in the target region.
- First beam foreseen for 2028

High-intensity Muon Beams (HIMB)



MUSE @ J-PARC



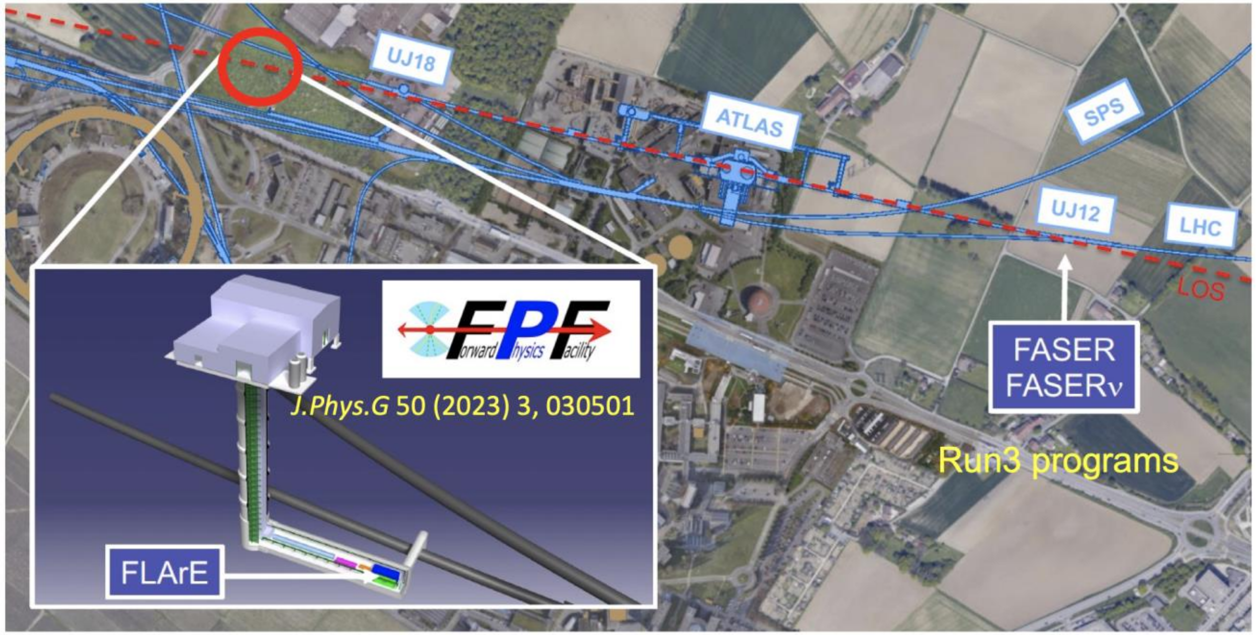


- commissioning of an ultra-slow muon beam through the laser ionization of thermal muonium.
- Needs a breakthrough in cooling technology
- Material Science experiments ongoing

Synergies

J Bian

Fast Forward Facility (CERN)

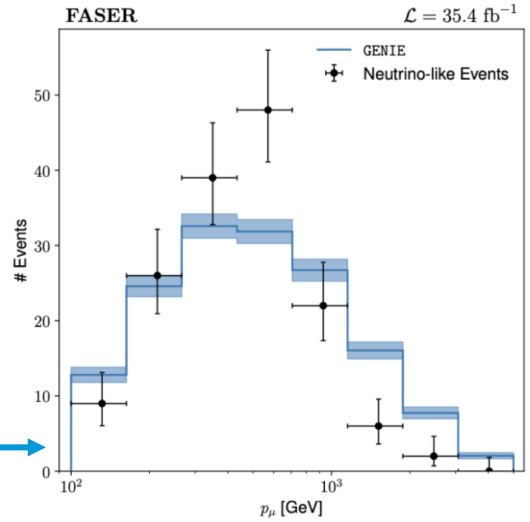


Motivations

- Neutrino Physics (cross sections, flux for tau neutrino, etc)
- Dark Matter search

- FPF: Proposal to create forward underground space for experiments during HL-LHC.
- FLArE: a liquid argon time projection chamber (LArTPC) detector for FPF to detect very
- high-energy neutrinos and search for dark matter at LHC@CERN
- The central goal of FPF is to extend the current LHC forward physics programs into the HL- LHC era with x10-100 exposure

2018 pilot emulsion detector with 11 kg was deployed for 12.2 fb-1

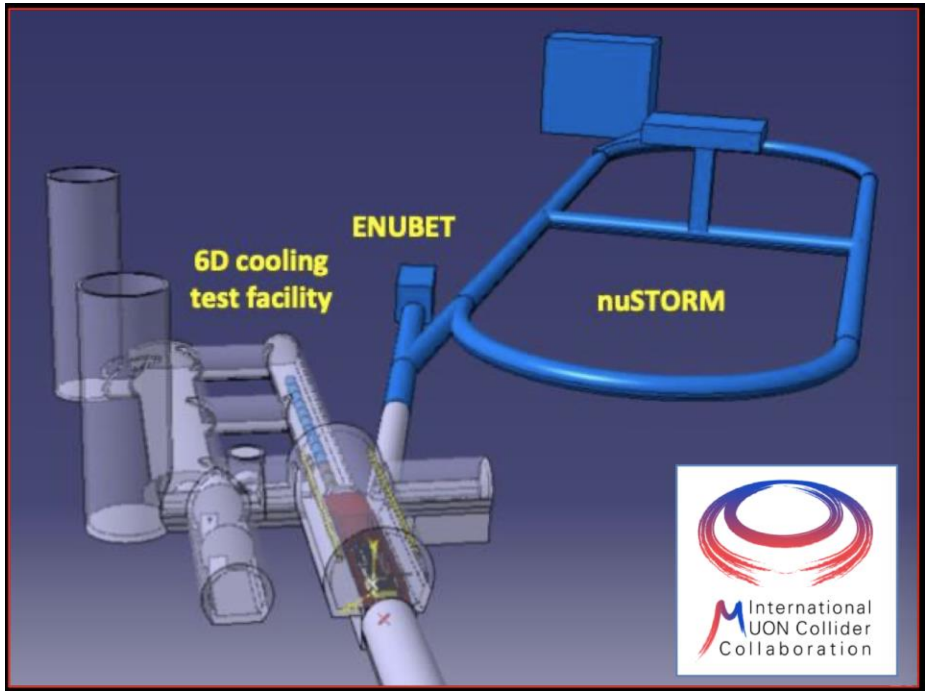


Phys.Rev.Lett. 131 (2023) 3, 031801

Synergies

J. Pasternak

νSTORM



- %-level *electron* and muon neutrino cross-sections
- Neutrino energy scan; spectrum at each point precisely known
    - Exquisitely sensitive BSM & sterile neutrino searches
    - Serve as muon accelerator test bed
- a step towards the muon collider:
    - Proof-of-principle of high brightness stored muons beams

Facility:

- Lattice re-optimization (target to detector simulations)
- Energy range to overlap with Dune/Hiper-K
- Baseline to use Dune G-Ar detector

Exploring the Physics Opportunities of nuSTORM

Thursday 6 Apr 2023, 08:00 → 18:00 Europe/London

IoP Building, London

https://conference.ippp.dur.ac.uk/event/1169/

Description More information can be found at the main IOP website: https://iop.eventsair.com/nus2023/

Join on Zoom here: https://cern.zoom.us/j/69597357629?pwd=dCtYMXZNeTM3RTJIYVBsWVNKQmNtQT09

Recordings: part 1 MhE^W=!6, part 2 S33$$fP5 (auto-delete in 15 days, i.e. on ~ 21 April)

Synergies

M. Chung

Overview of Accelerator Programs in Korea and Their Potential Contributions to Neutrino/Muon Physics

Parameter	PLS-II	KOMAC	PAL-XFEL	RAON
Species	Electron	Proton	Electron	Proton ~ Heavy ion
Energy	3 GeV	100 MeV	10 GeV	200 MeV/u for U^{79+}
Beam current	400 mA	20 mA (1.33 ms)	3 kA (0.2 nC/100 fs)	8 pμA U^{79+}
Rep. Rate	499.973 MHz (ring)	60 Hz	120 Hz	CW
Accelerating Structure	NC S-band (linac) SCRF (ring)	Vane-type RFQ 350 MHz DTL	3 Bunch Compressor 2.856 GHz (S-band)	SCRF: QWR (81.25 MHz), HWR (162.5 MHz), SSR (325 MHz)
Research Areas	Condensed matter, Surface/Cluster, Material science, Chemistry/Biology, Energy/Medicine	Nano, Bio, IT, Space, Radiation, Medical etc.	Atomic/Molecular, Condensed matter, Surface/cluster, Material science, Chemistry/Biology, Non-equilibrium plasma, Warm-dense plasma	Nuclear physics, Bio-medical science, Material science, Neutron science
	~Typical 3GSR	~ front end of SNS/ORNL	~ LCLS/SLAC	~ FRIB/MSU

Muon beams, radiation hard materials

High and low energy Muon beams

Target and materials (high DPA)

Final remarks

- Accelerators are necessary for the physics we want to do
- Future improvements/ideas/facilities are necessary to continue improving our results

We had many interesting talks and discussions.
Thank you!