Overview

- Test Beam goals
- Detectors and Setup
- Beam Requirements
- Infrastructure Requirements
T2K Near Detector Upgrade

~1ν/cm²/s at T2K Far detector (295 km away) @ 750 kW proton beam power

Super-Kamiokande
Mt. Noguchi-Goro 2,924 m
Mt. Ikeno-Yama 1,360 m
1,700 m below sea level
Neutrino Beam
295 km

Super-Kamiokande
50 kt Water Cherenkov detector (Fiducial 22.5 kt)

J-PARC

Near Detectors

INGRID
on-axis detector

T2K Neutrino Beamline
181 MeV LINAC
3 GeV RCS
30 GeV Main Ring

off-axis detector : ND280
The upgraded ND280 design

The new detectors configuration is very efficient for high angle tracks

Two new High-Angle Time Projection Chambers (HA-TPC)

A highly segmented scintillator active target (SuperFGD)

No changes to other detectors

UA1 Magnet CERN

Present detector configuration

Six ToF Scintillator planes all around

ν beam

μ

ν beam
Test Beam Goals

1) Track spatial resolution (with zero B field)
   - with lever arm ~ 70cm to 150cm
   - scan along drift distance (100cm)
   - Inclined tracks ($\theta, \phi$) wrt drift direction

2) track dE/dx resolution & PID capability
   - e, $\mu$, $\pi$, K, p momentum range 0.4 – 2GeV

3) Electric Field & geometry distortions
   - E field transv. < $10^{-3}$ & longit. ~ uniform < $10^{-3}$
     → probing near walls & corners
     → probing uniformity of drift time
   - Spatial & Timing alignment of 8 sensors

4) assess multiple scattering across walls
Detectors & Setup

- Main detector under test → large volume TPC
  ½ HA-TPC → 1.9m x 1m x 1m → ~ 200kg
- Equipped with 8 ERAM mods. (1 anode side instrumented only)
- Cathode → - 30kV
- T2K gas mix (Ar:CF₄:iC₄H₁₀ =95:3:2) → premix bottles
  → operating at 1 bar in overpressure by ~ 5 mbar
  → gas flow ~ 50 L/h
- Must perform preliminary purging @ PS hall
  → we will procure the gas in proper amount (bank 12 bottles)
- ? preliminary data taking downstream T9 control room with muons ? 1 week in advance ?
Detectors & Setup

- **Main detector under test → large volume TPC**

- **Ancillary detectors (beam line)**
  - 2x Thr. Cherenkov Counters → crucial to test PID
  - Beam trackers → XDC ? access to signals ? To our DAQ ?

- **Ancillary detectors (ours)**
  - TPC prototype → external tracker (300μm resolution) → tested at SPS Test Beam Nov. ‘21
  - Silicon strip tracker stations (10x10cm²) → external tracker (30μm resolution) → “
  - Scintillators → TOF system to select particles (e,mu/K/p) at trigger level: Level Arm ! → Scint. location ?
  - Lead-glass blocks → calorimeter / muon catcher

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*Configuration Test Beam @ PS T9 2018*
### Trigger & Readout conditions:

- Limited by readout deadtime $\sim 3\text{ms}$
  - Readout less than 100 triggers/spill $\rightarrow$ intensity $\sim O(10^2 \text{ pps})$
  - Need selective beam conditions $\rightarrow$ use hadron enriched / electron enriched
  - Need selective trigger conditions $\rightarrow$ use ToF & Cherenkov & muon catcher
    - Good $e/\mu/\pi/K/p$ separation at trigger level
  - But need $x100$ higher beam rate for $K$ and $p$ $\rightarrow$ intensity $O(10^4 \text{ pps})$ for some runs

### Note:

- Pile-up $\rightarrow$ would prefer to avoid 2 particles within $50\mu s$ $\rightarrow$ max rate $\sim 10^4 \text{ pps}$
- Also we must avoid space charge effects $\rightarrow$ max rate $\sim 10^4 \text{ pps}$

- With 3 spills/Super-Cycle $\times$ 1800 SC/day $\times$ 50 trigg/spill $\rightarrow$ $\sim 300k$ triggers/day $\rightarrow$ OK
- … but would it be possible to have more than 3 spills per super-cycle? (max is 6 …)
  (or extract 600ms instead of 400ms? $\rightarrow$ lower instantaneous intensity)
Secondary Beams

- Secondary beamlines T9/T10/T11 with options for pure $e^+/-$, pure hadron and pure muon beams

- T9 beam more suitable for pure $e^+/-$ / hadron / muon @ lowest momenta

- Would it be possible to minimize material budget (+ evacuate Cherenkovs’) along the beam line for improving very low p hadron beams (intensity & p spread)?
Infrastructure needs

• Cabling
  - main reaodut → x2 optical fibers (special filbers)
  - trigger & control signals in CR (i/o) → about x10 coax. cables
  - ethernet cables x5 for DAQ & HV / LV Power Supplies control

• HV & LV PS
  - Cathode HV = -27kV (< 50μA current)
  - Micromegas HV = +400V (< 5nA current)

• Gas → operating at 1bar (5mbar over-pressure)
  - main gas → T2K premixed bottles (ours)
  - ls N₂ available for purging ? In the area ? Outside T9 ?

• Platforms / structures (ours)
  - our dedicated turn-table

• Racks
  - 1 gas rack (ours)
  - 1 electornics rack (ours)
  + 1 additional

• Water chiller
  - ours
Additional Material
Design considerations – new HA-TPCs

new Field Cage → thin & low density walls  
→ thin walls made of solid insulator walls (composite material)  
→ minimize dead space & maximize tracking volume

new Micromegas sensors → new “Embedded Resistive Anode Micromegas”  
→ charge sharing: same spatial resolution with lower pad density  
→ intrinsic spark protection: simplified FE electronics

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Overall x x y x z (m)</td>
<td>2.0 x 0.8 x 1.8</td>
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<tr>
<td>Drift distance (cm)</td>
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<td>Magnetic Field (T)</td>
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<td>Electric field (V/cm)</td>
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<td>Gas Ar-CF$_4$-iC$<em>4$H$</em>{10}$ (%)</td>
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<td>Drift Velocity cm/μs</td>
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<td>Sampling frequency (MHz)</td>
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<td>N time samples</td>
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High Angle TPCs to measure charged particles (E~200MeV-2GeV) exiting the new active target (superFGD)
RMM0 & HARP FC → Test Beam 2018 at CERN

Results of the analysis are published in 2020: NIMA 957, 163286

15 Days
@ CERN PS T9 Beam line
Test Beam 2018

**BEAM TRIGGER** (NIM logic) selecting particles by combining:
- timing resolved coincidences of scintillators along the beam line → ToF trigger
- threshold Cherenkov counters coincidences with scintillators → Cherenkov trigger
- Muon separation → downstream Muon catcher

Collected data samples
- **Beam momentum** = +/- 0.5 / 0.8 / 1.0 / 2.0 GeV/c
- e/π/μ/p separation at TRIGGER LEVEL

**55Fe SOURCE** on cathode

**CR TRIGGER**
large Horizontal scintillators