

T2K Near Detector Upgrade

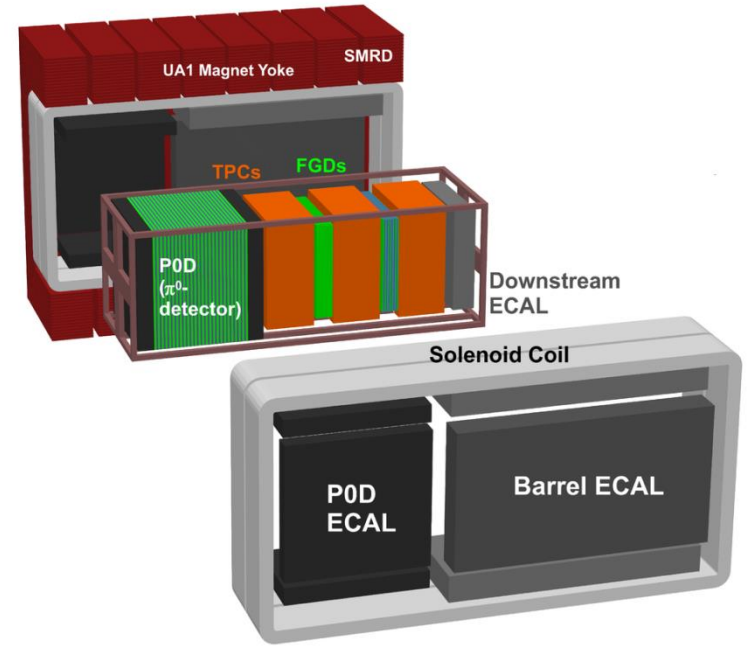
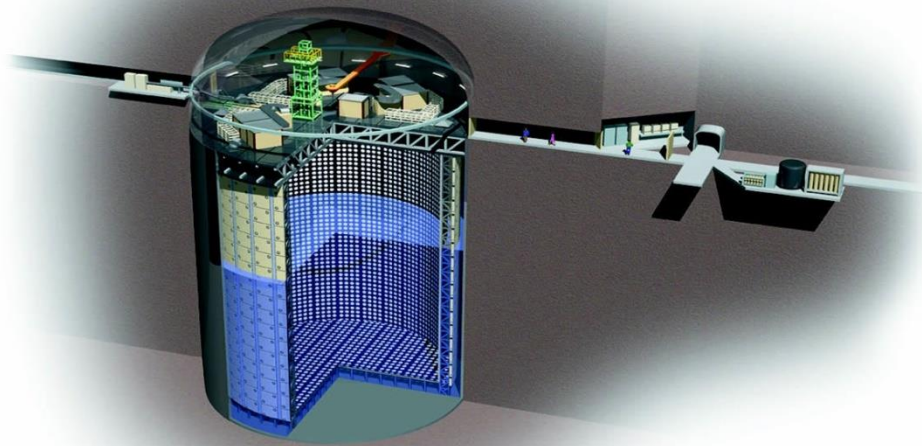
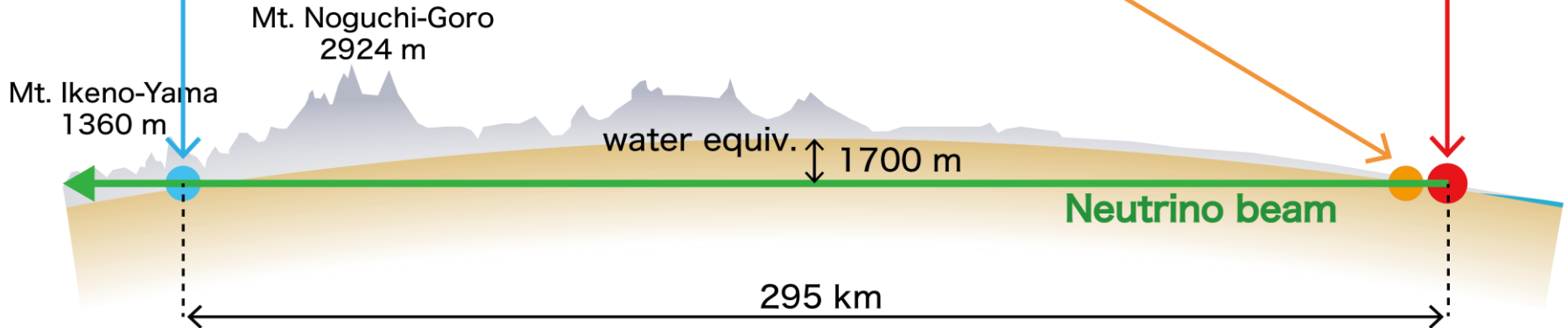
Thorsten Lux



Super Kamiokande

Near Detector

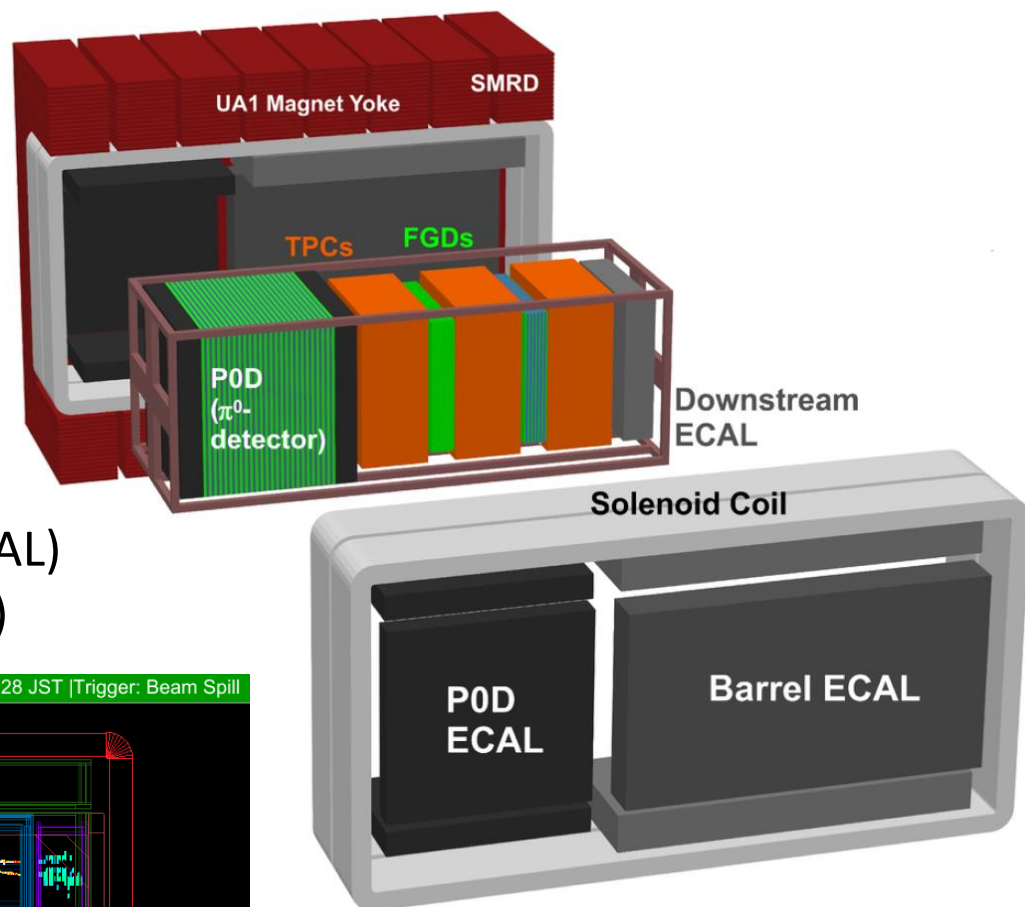
J-PARC



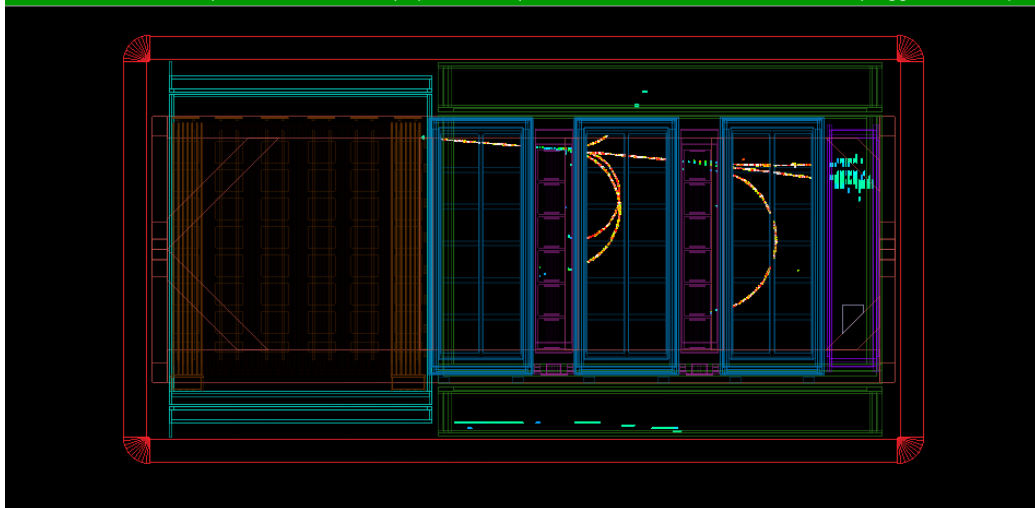
ND Purpose: Measurement of neutrinos before oscillation

ND components:

- UA1 magnet: 0.2 T
- π^0 detector (POD)
- 2 Fine Grain Detectors (FGD):
 - target, FGD2 with H₂O
 - XY scintillator bars
 - 1 ton each
- 3 Time Projection Chambers (TPC)
- Electromagnetical Calorimeter (ECAL)
- Side Muon Range Detector (SMRD)



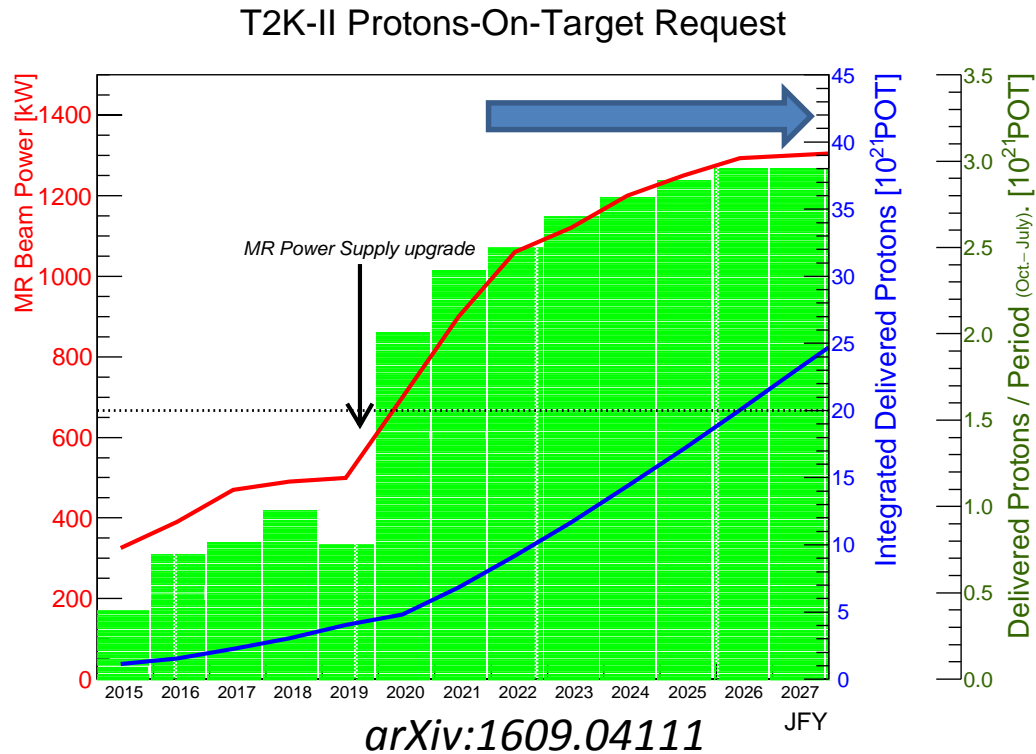
Event number : 27404 | Run number : 8115 | Spill : 51004 | Time : Mon 2012-01-23 06:04:28 JST | Trigger: Beam Spill



T2K-II

arxiv:1609.04111

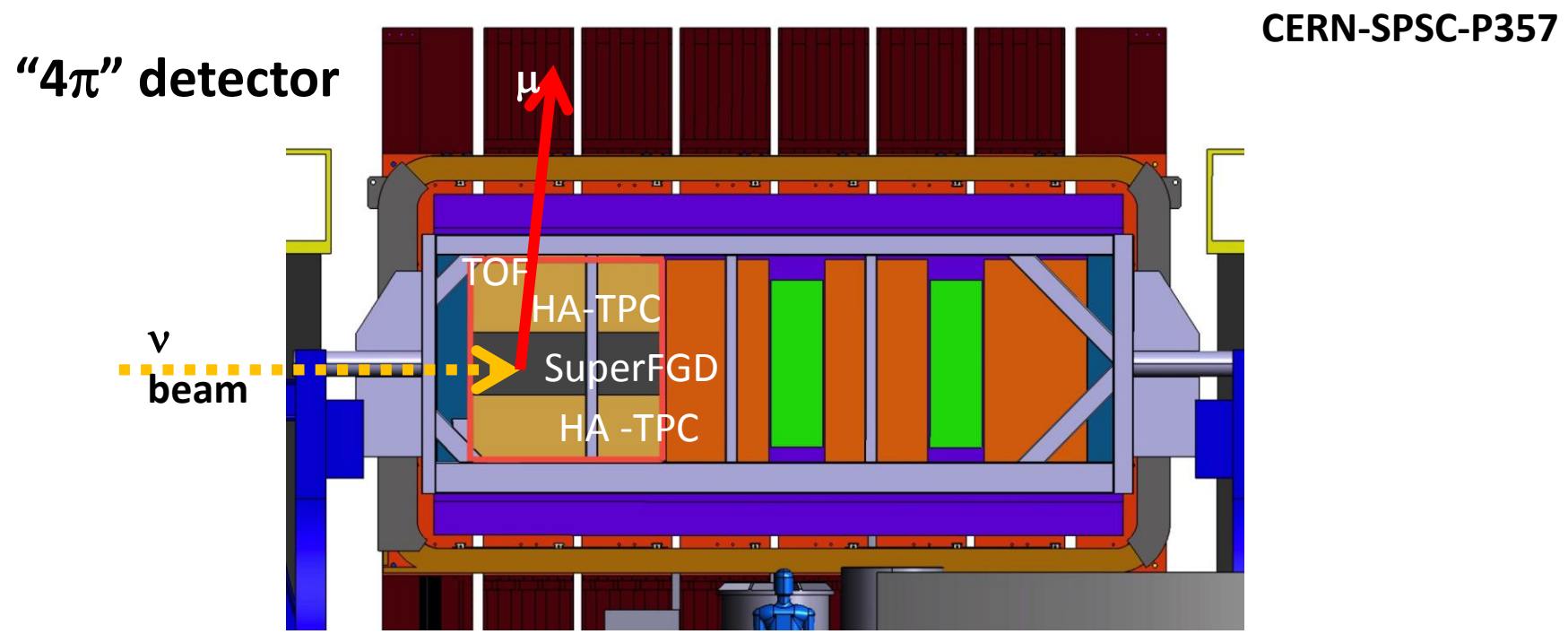
- aim: systematics from 5-6% to 4%
- beam power upgrade: 485 kW \rightarrow 1.3 MW
- statistics: 3E21 POT (2018) \rightarrow 20E21 POT (2026)
- Aim for CPV observation in optimal scenario at 3σ



N280 Upgrade replace POD by:

- 1 fine grained scintillator target (SuperFGD)
- 2 high angle TPCs (HA-TPC)
- 6 time of flight panels (TOF)

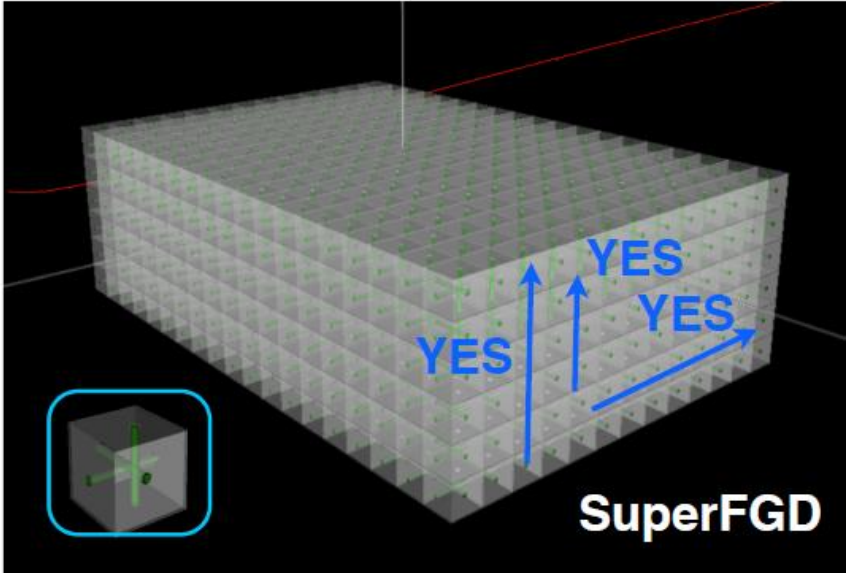
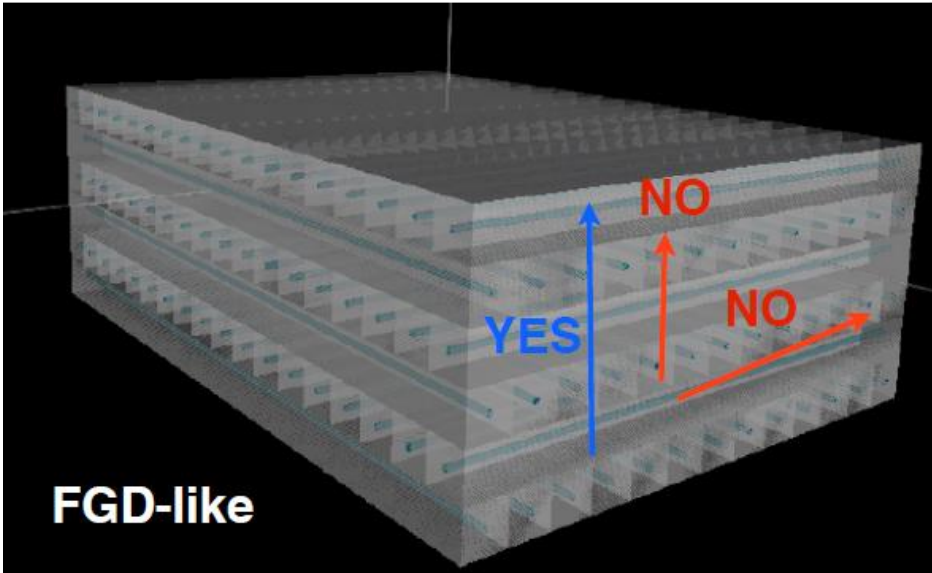
	Current (FGDs)	Upgrade (FGDs + SuperFGD)
Target mass (tons)	2.2	~4.2



SuperFGD

- scintillator, WLS fibers + MPPCs
- classical 2D approach reconstruction limitations
- new 3D approach: 1x1x1 cm³ cubes with 3 WLS fibers
- size: ~1.8x0.6x2 m³

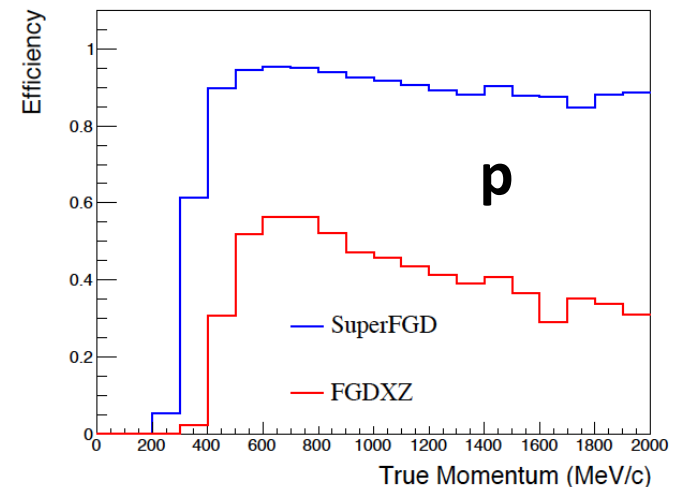
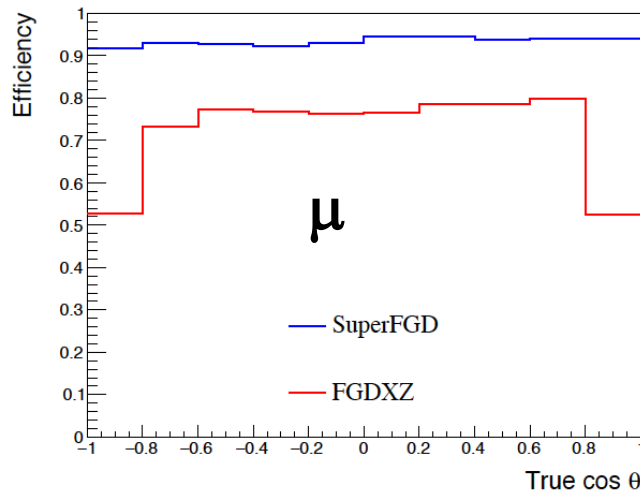
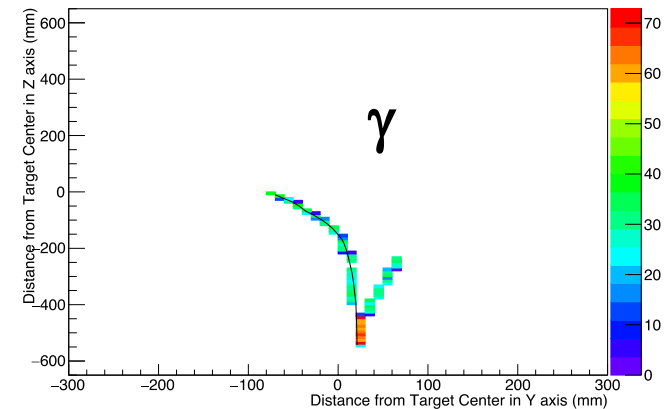
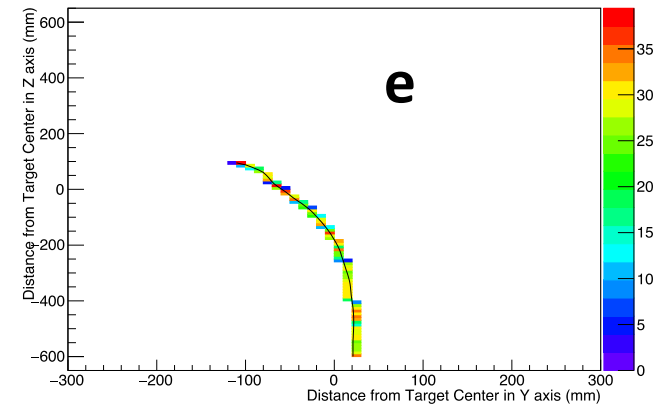
Parameter	Cube edge: 1 cm
# of cubes	2,160,000
# of channels	58,800
Total fiber length	65 km



SuperFGD

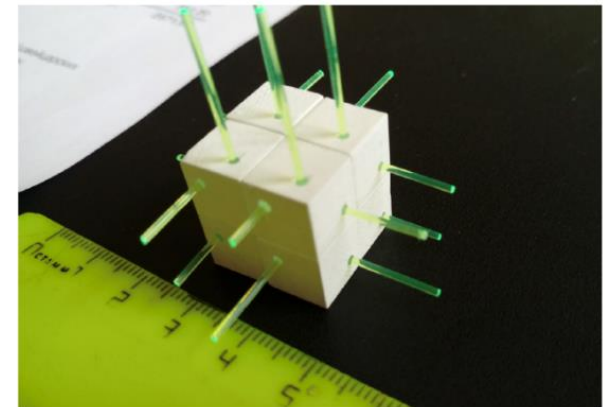
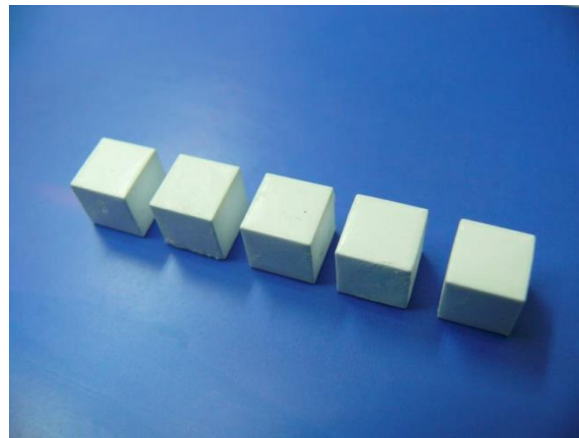
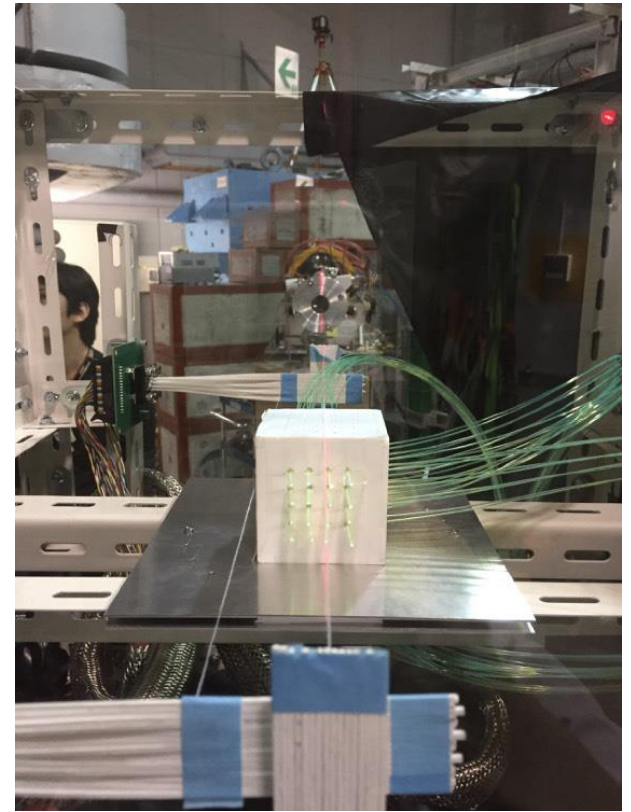
Simulation studies:

- high granularity allows excellent pattern recognition
- light yield from the 3 fibers helps to distinguish 1 from 2 particles => e/γ separation
- significant improvement on \mathbf{p} reconstruction efficiency



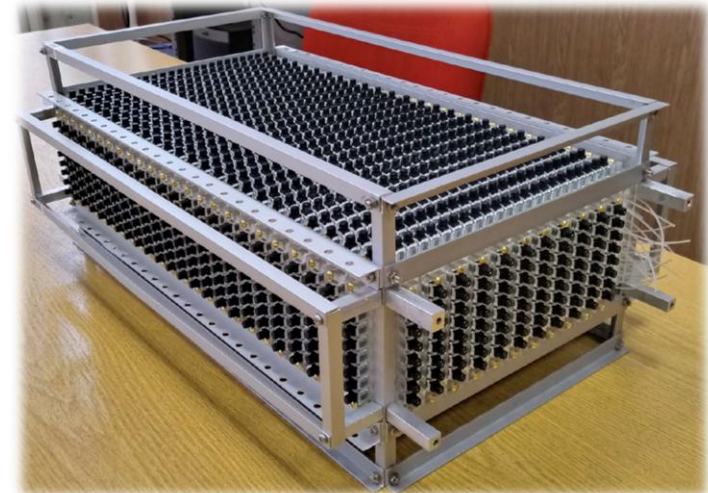
SuperFGD

- Cube production by injection mold method at INR RAS (uncertainty $\sim 35 \mu\text{m}$)
- Reflector coating ($\sim 50 \mu\text{m}$) by chemical etching Uniplast (Russia)
- 2017: prototype of 5x5x5 tested at CERN testbeam:
 - light yield
 - cross talk
 - timing resolution



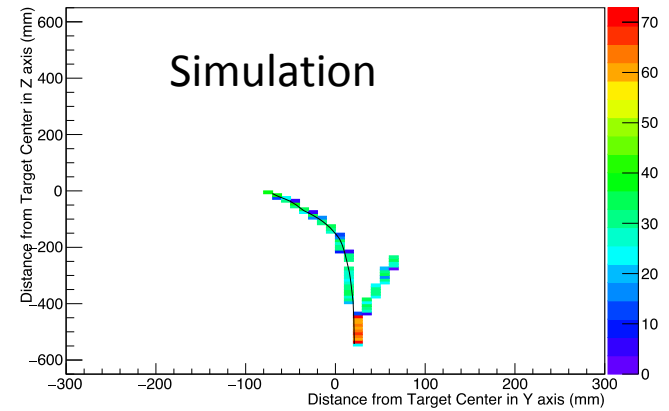
SuperFGD: Is it scaleable?

- prototype of 9216 cubes
- size: 8x24x48 cm³
- 1728 fibers/MPPCs
- 3 type of MPPCs
- adapted Baby MIND electronics (based on CITIROC chip) for readout
- Testbeam at CERN beginning of July
- e, μ , π , protons and γ (!)



SuperFGD:

- very successful data taking
- important step towards full size detector
- detailed data analysis ongoing

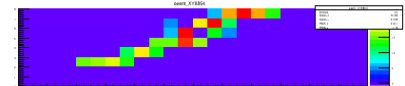
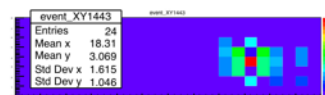
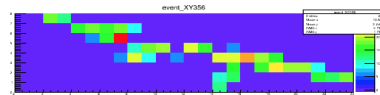
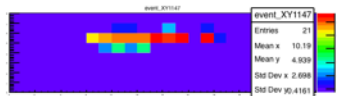


Single track

Pion beam

Stopping proton

Photon beam

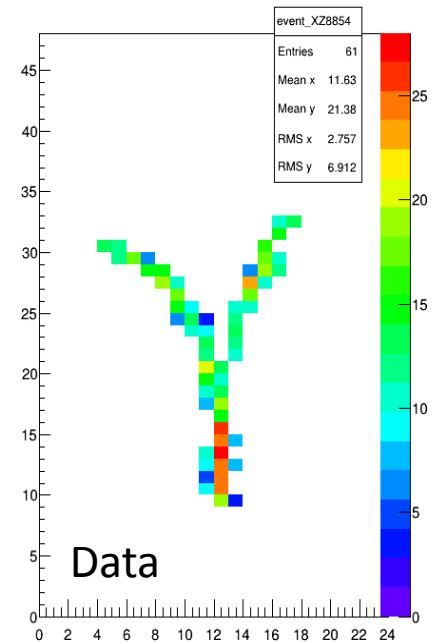
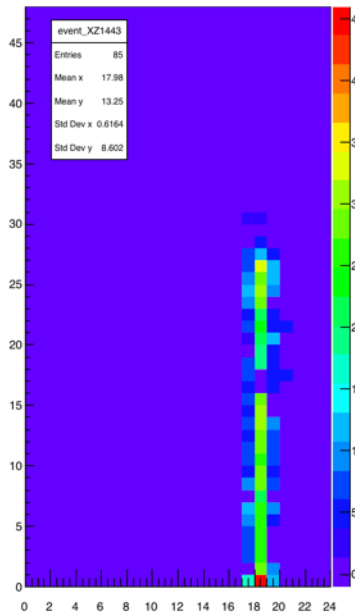
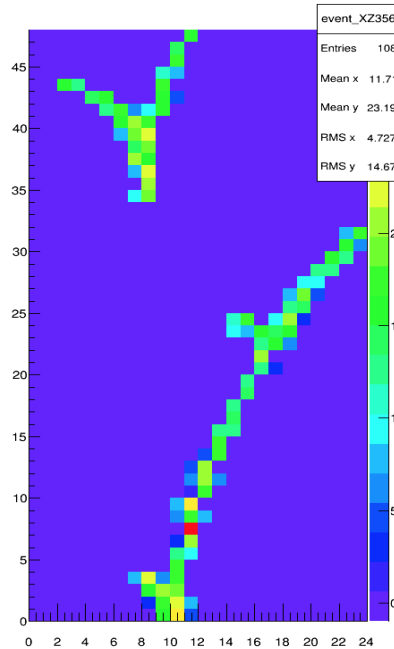
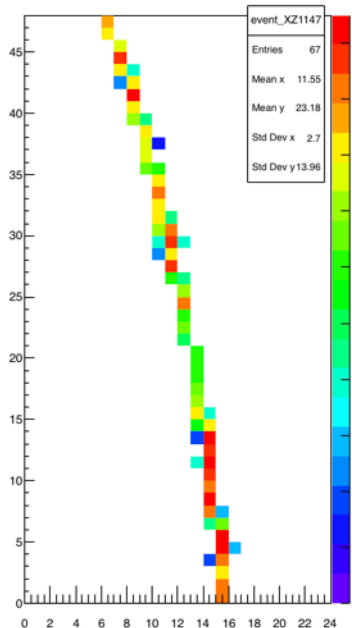


event_XZ1147

event_XZ356

event_XZ1443

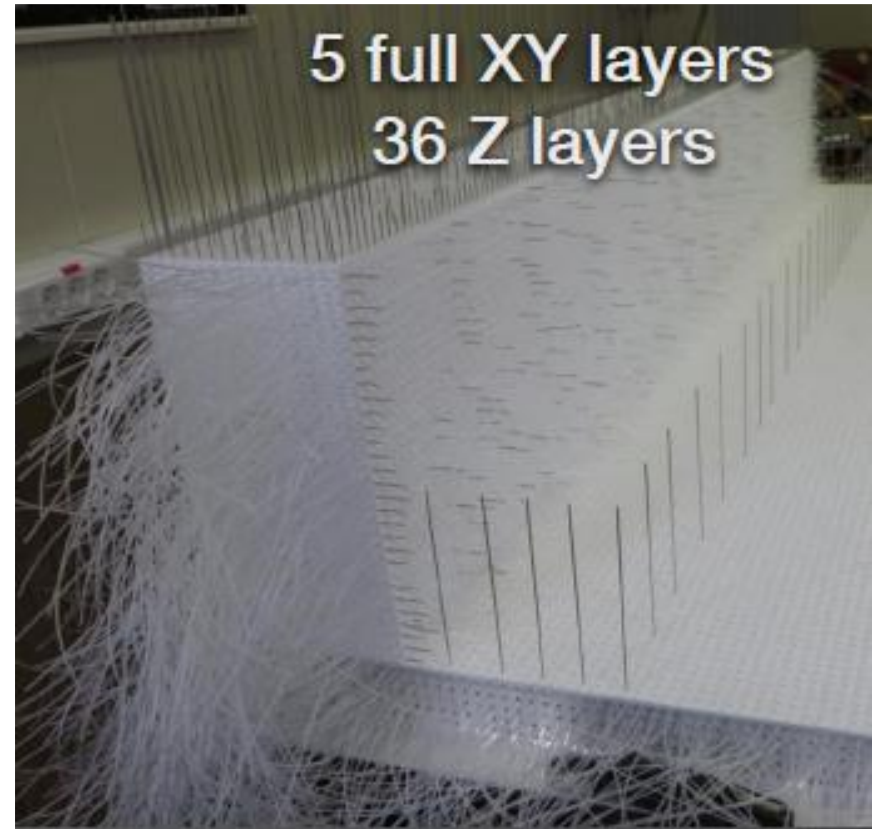
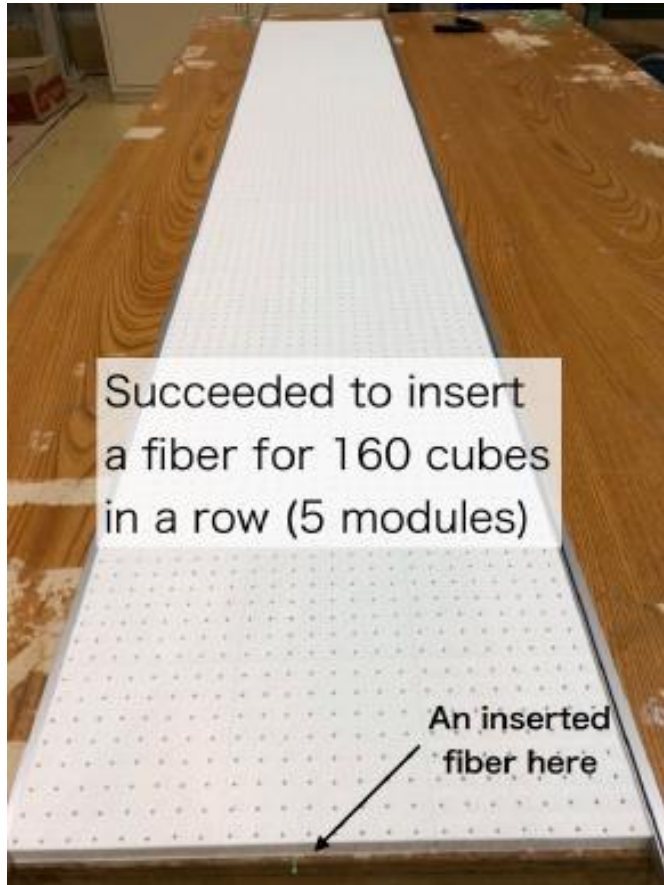
event_XZ8854



Data

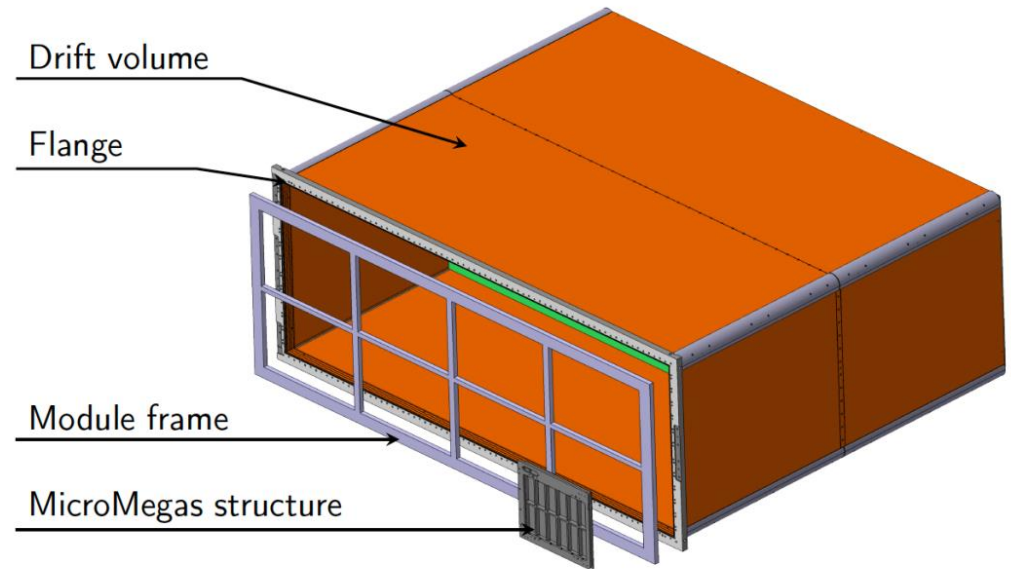
SuperFGD:

- significant progress towards assembly of final detector
- 2 methods: fishing line vs welding
- Review panel end of October
- Production start 2020



HA-TPC:

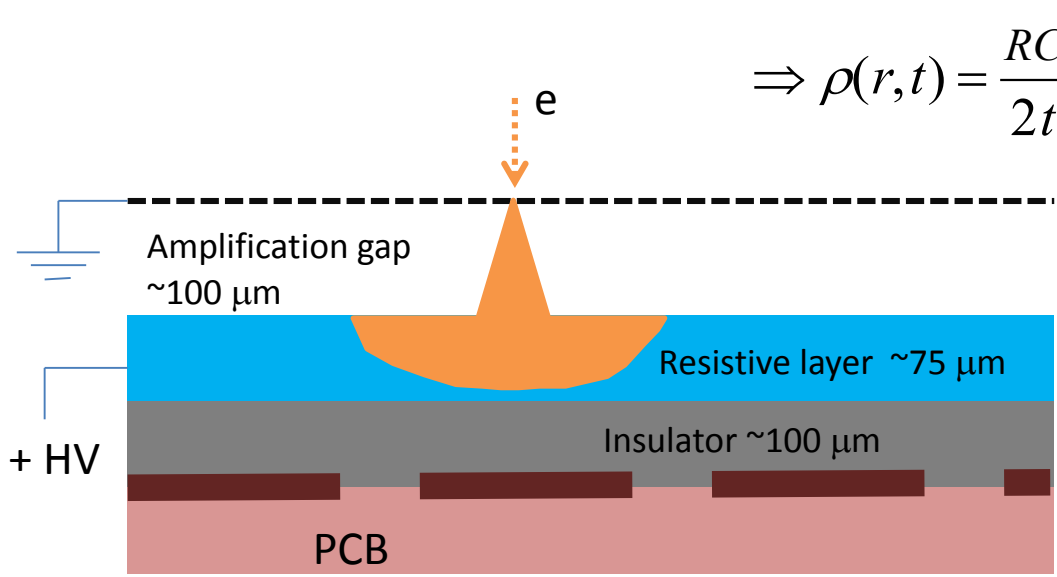
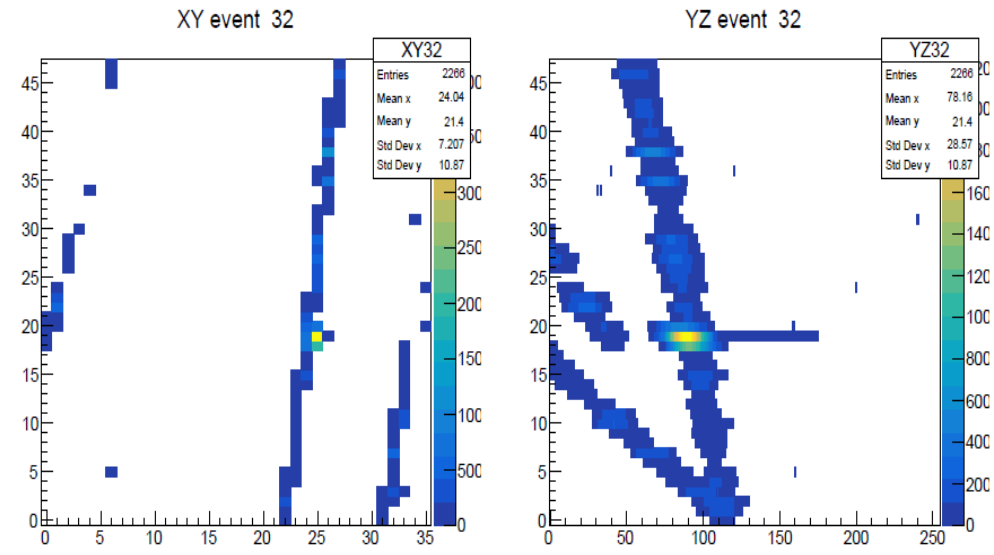
- 2 rectangular TPCs
- inner dimensions:
 - 1.8 m wide
 - 0.7 m height
 - 2 x 1.06 m drift
- single gas volume
- composite material FC
- radiation length: 2-3% X_0
- 8 resistive MicroMegas
- T2K gas: 93% Ar, 3% CF₄, 2% iC₄H₁₀
- Cathode voltage: ~25 kV
- readout electronics based on AFTER chip
- 10% $\Delta p/p$ at 1 GeV/c



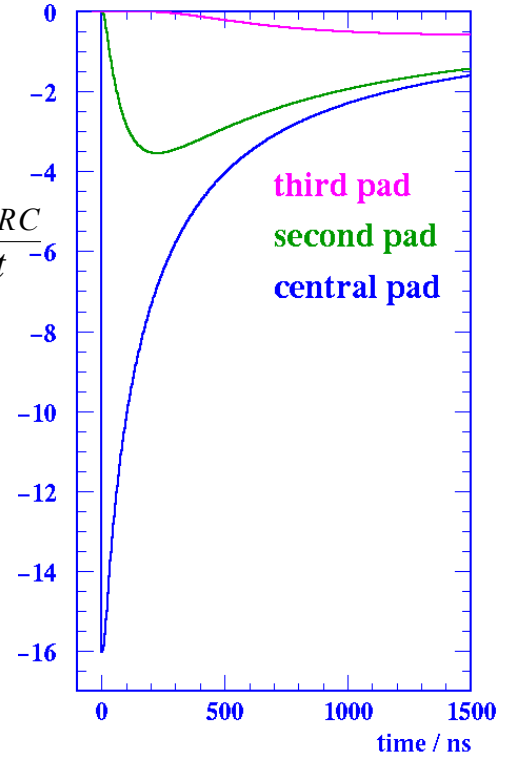
Material	Thickss (mm)
<i>Copper coated polyimide film</i>	~ 0.15
<i>Aramid Fiber Fabric (Kevlar)</i>	2.00
<i>Aramide HoneyComb panel</i>	30.00
<i>Aramid Fiber Fabric (Kevlar)</i>	2.00
<i>Polymide film (insulation)</i>	~ 0.10
<i>Strips (double later) on Kapton foil</i>	~ 0.15
TOTAL	~34.40

HA-TPC:

- avalanche size in MM few microns
=> no charge sharing between pads
- adding resistive layer to spread charge (*NIM A518 (2004) 721*) => reduction of electronics channels
- testbeams at CERN (2018, submitted to NIM) and DESY (2019)



$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{-\frac{r^2 RC}{4t}}$$



HA-TPC: Field Cage

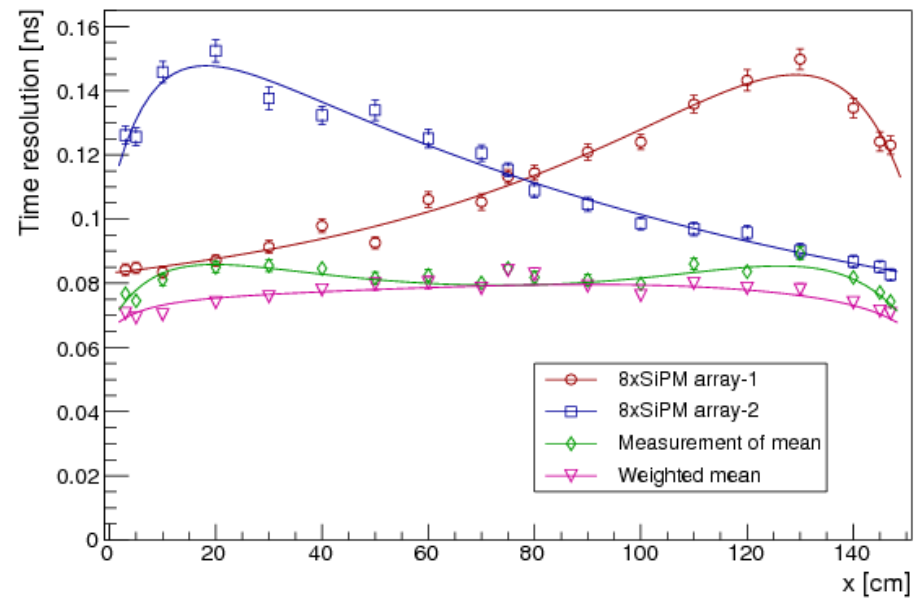
- Design and construction of mold (INFN Padova and INFN Bari)
- prototype of field cage constructed in April 2019 at NEXUS (Spain)
- Many small problems identified and solved at INFN Legnaro/Padova
- Since August 2019 at NP07 Upgrade facility at NP Hall at CERN
- Data taking foreseen from October 2019 on
- Final chambers under design
- Start of production will start spring 2020



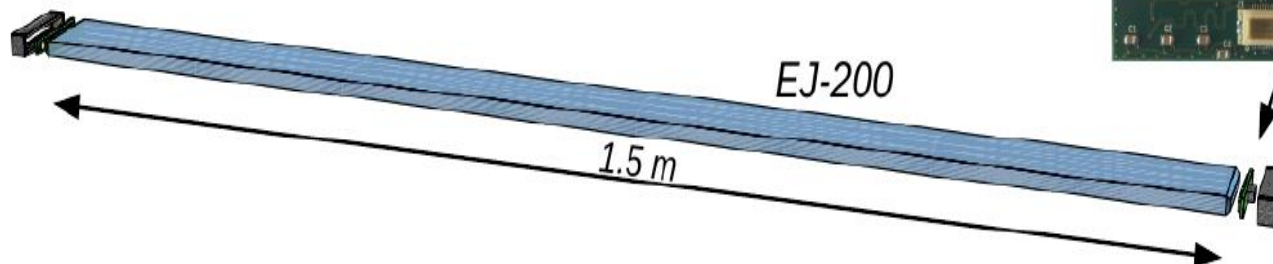
TOF: JINST 12 (2017) no.11, P11023 (arXiv:1709.08972)

Baseline choice:

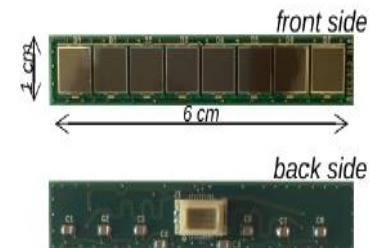
- Cast plastic scintillator: EJ-200
- 8 SiPM (6x6 mm²) directly coupled to scintillator
- readout from both sides
- tested in CERN testbeam 2017
- ~70 ps time resolution for 1.5 m bars achieved



Test module

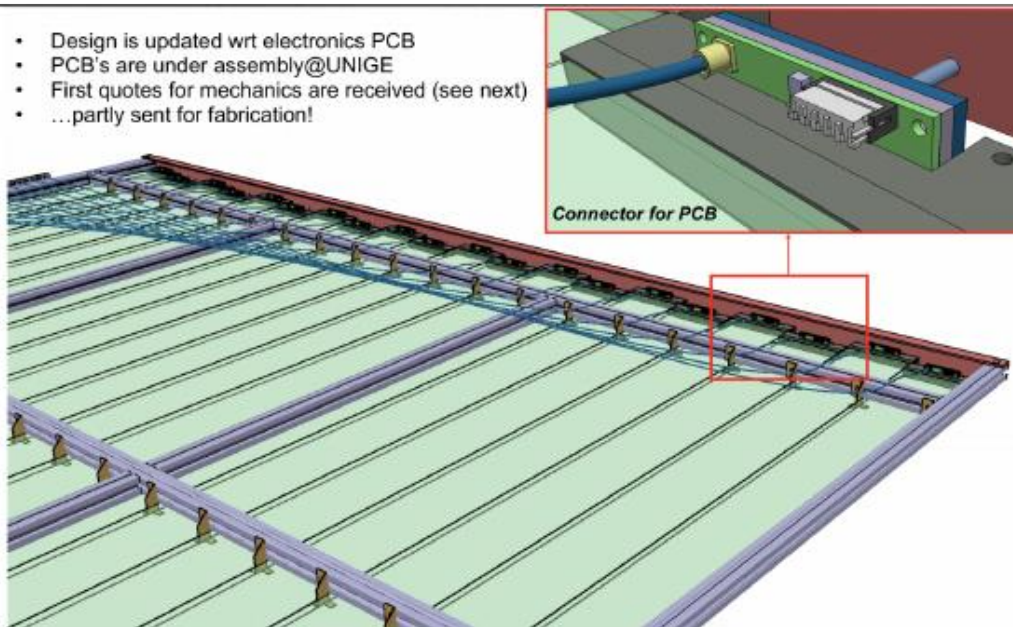


External PCB with sensors

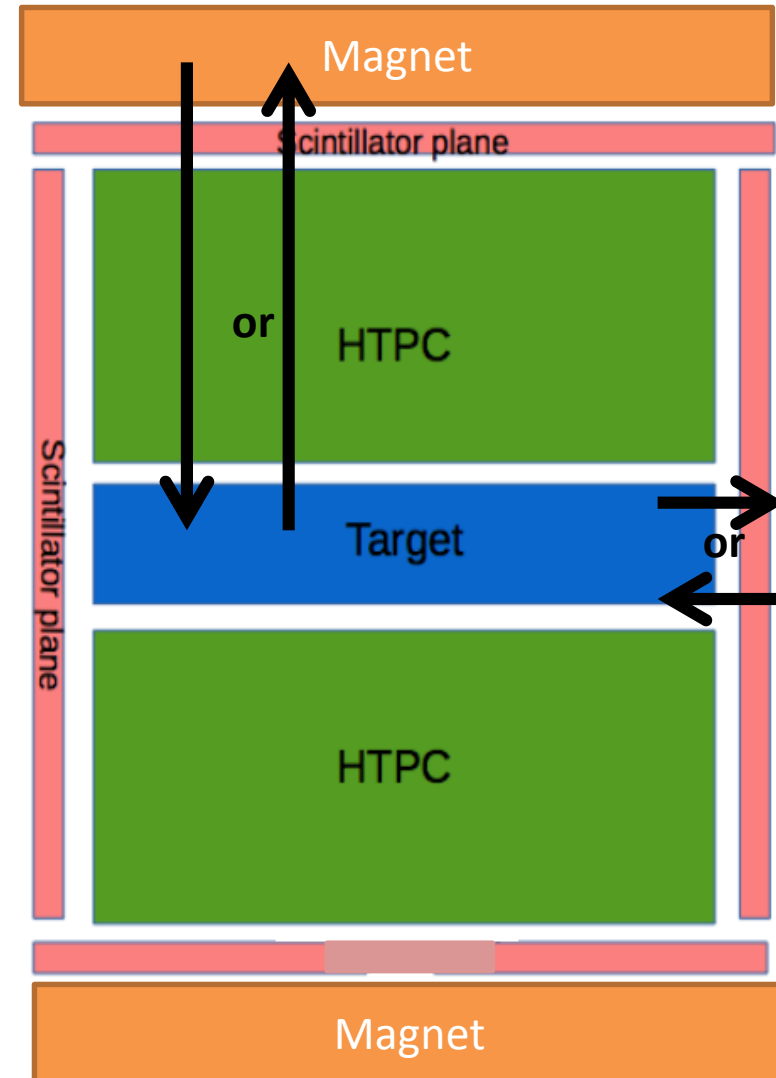


TOF:

- 6 panels with 20 bars of : $12 \times 230 \times 1 \text{ cm}^3$
- purpose: identify if particles from target to magnet and improve backward efficiency for current tracker
- First 60 bars delivered to CERN
- Assembly done until end 2019



Franck CADOUX (UNIGE), Paris July, 22-23



Commissioning at CERN:

- “BabyBasket” designed and currently constructed
- originally only for TOF panels
- extended to TPCs and possibly even final SuperFGD
- Full integration test before Japan possible



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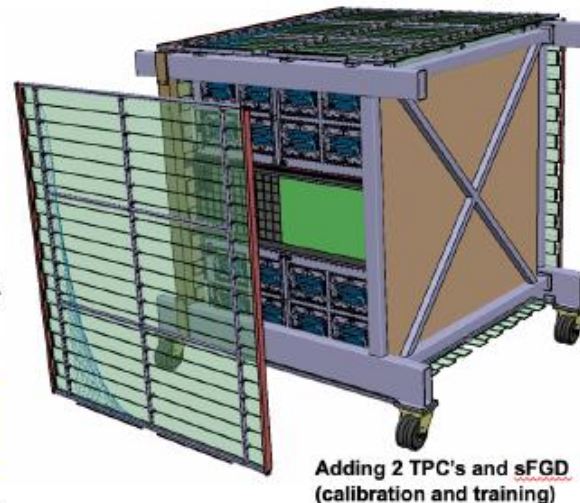
Design evolution... starting from TOF!

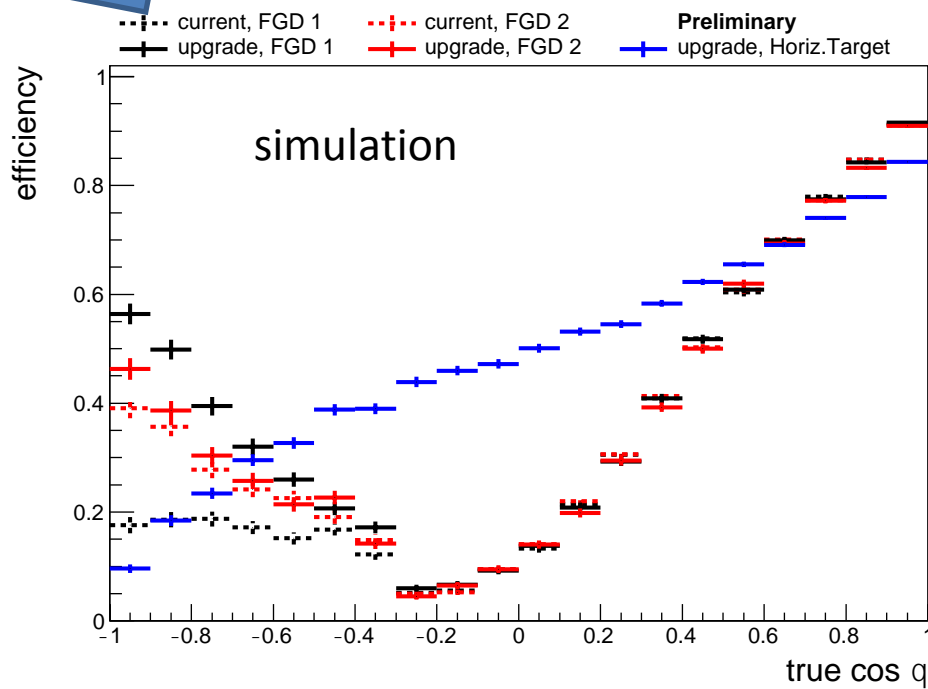
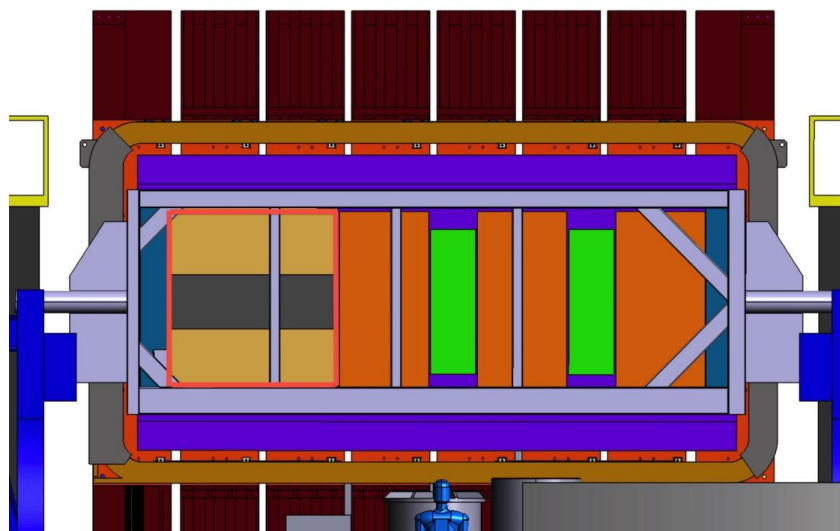
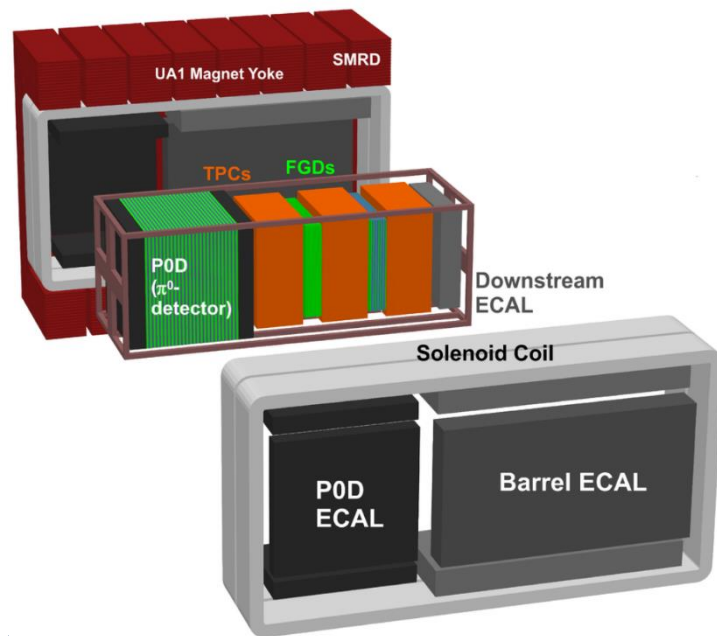
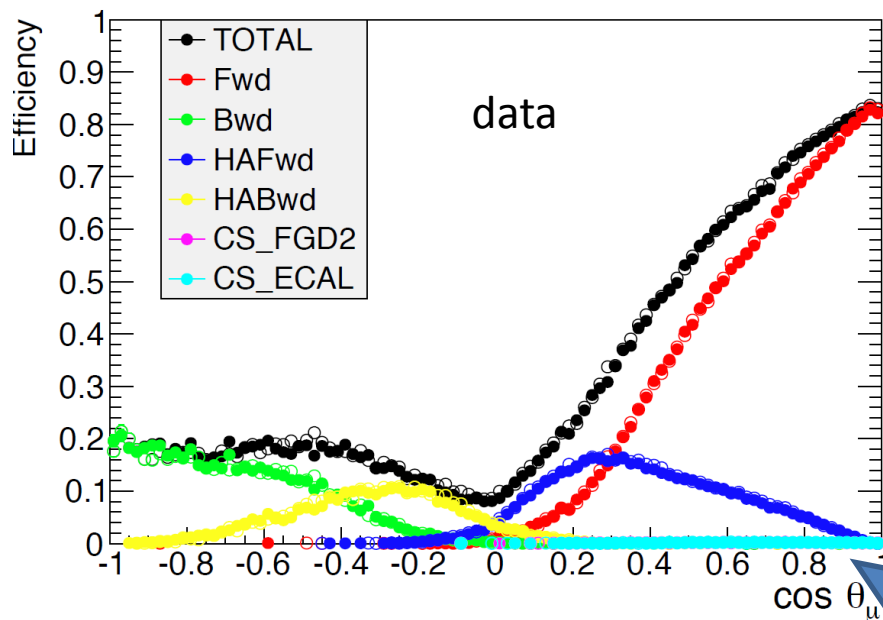
Original idea (TOF assembly for calibration)



A stand to exercise with Insertion, mechanical fixation, services, envelope check... and used for calibration @ CERN (and J-Parc)

Evolution towards “integration” approach





Conclusions

- **ND280 Upgrade for T2K-II**
 - High angle acceptance and low momentum measurement by SuperFGD, HA-TPCs and ToF counters
 - R&D and simulation studies in well advanced
 - Acknowledgement: Many thanks to CENF for support!
 - TDR published January 2019
 - T2K Upgrade accepted at CERN NP07 project
- **Schedule for the ND280 Upgrade:**
 - TOF production already started
 - HA-TPCs and SuperFGD production to be started in 2020
 - **2021: Installation and commissioning in Japan**