

Comité de Suivi Individuel troisième année



Lavinia Russo
Neutrino group LPNHE

conclusions (1)

slide from 2nd year CSI

[link to the indico of
2 CSI](#)

so far in my PhD:

- implementation of Martini's et al. model in GENIE MC generator
 - almost finalised project, we are writing a **paper**
- data analysis and data taking of the HA-TPC of the ND280 in T2K
 - spatial resolution and dE/dx resolution, we are writing a **paper**

updates since the 2nd CSI

my first paper as first author :) [link to the PRD paper](#)

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PHYSICAL REVIEW D **113**, 012006 (2026)

Implementation of the Martini-Ericson-Chanfray-Marteau RPA-based neutrino and antineutrino cross-section model in the GENIE neutrino event generator

L. Russo^{1,*}, M. Martini^{2,1,†}, S. Dolan³, L. Munteanu³, B. Popov¹ and C. Giganti¹

¹*Sorbonne Université, CNRS/IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE), Paris, France*

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³*CERN, European Organization for Nuclear Research, Geneva, Switzerland*

 (Received 22 August 2025; accepted 9 December 2025; published 13 January 2026)

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published on NIMA

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my second paper, as coauthor [link to the NIMA paper](#)

Nuclear Instruments and Methods in Physics Research A 1088 (2026) 171527

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journal homepage: www.elsevier.com/locate/nima

Full Length Article

Performance of the high-angle time projection chambers in the upgraded T2K off-axis near detector

K. Aivazelis^a, D. Attié^a, P. Billoir^b, A. Blanchet^b, G. Bortolato^c, S. Bolognesi^a, R. Boullon^a, N.F. Calabria^f, D. Calvet^{a,1}, M.P. Casado^{g,2}, M.G. Catanesi^f, M. Cicerchia^c, G. Cogo^c, G. Collazuol^c, P. Colas^a, D. Cotte^a, D. D'Ago^c, C. Dalmazzone^b, T. Daret^a, R. de Oliveira^d, A. Delbart^a, J. Dumarchez^b, K. Dygnarowicz^e, S. Emery-Schrenk^a, A. Ershova^a, G. Eurin^a, M. Feltre^c, C. Forza^c, A.N. Gacino Olmedo^b, A. Gambalonga^h, C. Giganti^b, F. Gramegna^h, P. Granger^d, R. Guida^d, M. Guigue^b, S. Hassani^a, D. Henaff^a, F. Iacob^c, C. Jesús-Valls^g, S. Joshi^a, R. Kurjata^e, M. Lamoureux^c, J.F. Laporte^a, M. Lehuraux^a, S. Levorato^c, A. Longhin^c, T. Lux^g, L. Magaletti^f, T. Marchi^h, D. Marchesini^c, L. Mareso^c, M. Mattiazzi^c, M. Mezzetto^c, B. Mehl^d, E. Miller^g, L. Mellet^b, L. Munteanu^d, Q.V. Nguyen^b, N. Ospina^f, Y. Orain^b, R. Palumbo^c, C. Pastore^f, J.-M. Parraud^b, E. Pierre^b, C. Pio^g, O. Pizzirusso^d, B. Popov^b, F. Pupilli^c, E. Radicioni^f, Ch. Riccio^a, L. Rinaldi^c, F. Rossi^a, S. Rothⁱ, L. Russo^b, S. Russo^b, A. Rychter^e, W. Saenz Arevalo^b, L. Scomparin^c, Ph. Schune^a, D. Smyczekⁱ, R. Spina^f, J. Steinmannⁱ, S. Suvorov^b, N. Thammⁱ, D. Terront^b, A. Teixeira^d, F. Toussenel^b, V. Valentino^f, D. Vargas^g, M. Varghese^g, G. Vasseur^a, C. Vuillemin^a, U. Virginet^b, Ch. Winterstein^a, U. Yevarouskaya^b, M. Ziembicki^e, M. Zito^b

conclusions (2)

slide from 2nd year CSI

[link to the indico of
2 CSI](#)

plans for the future

only on-going project

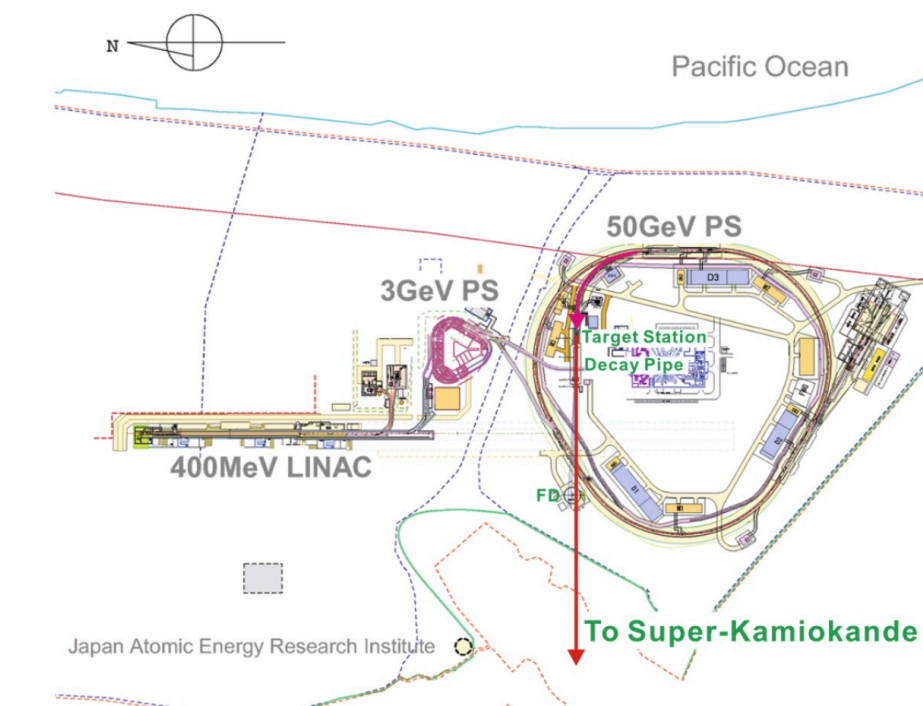
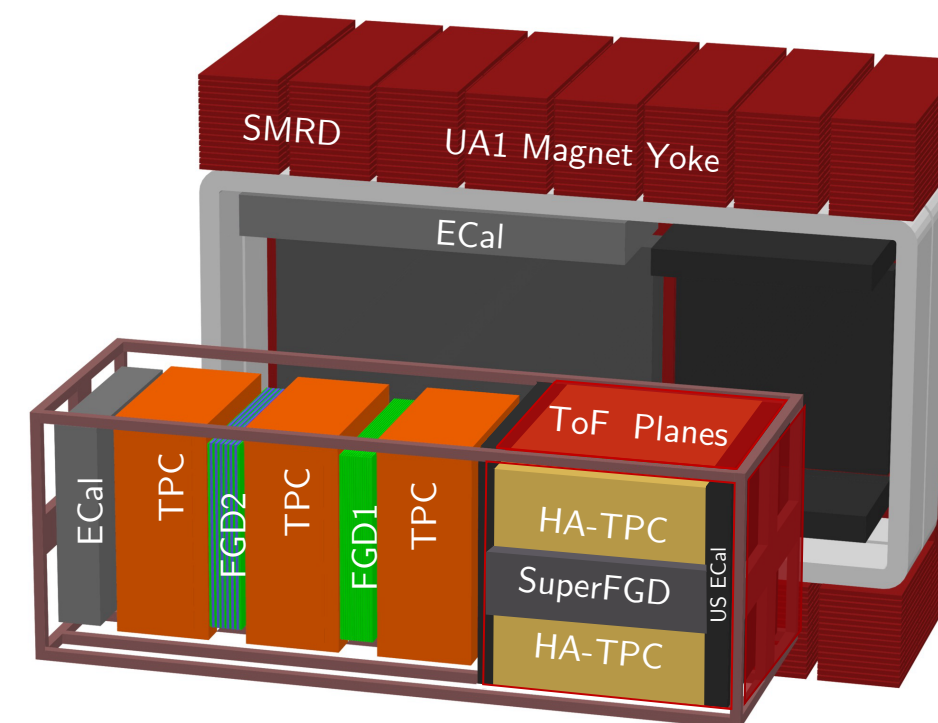
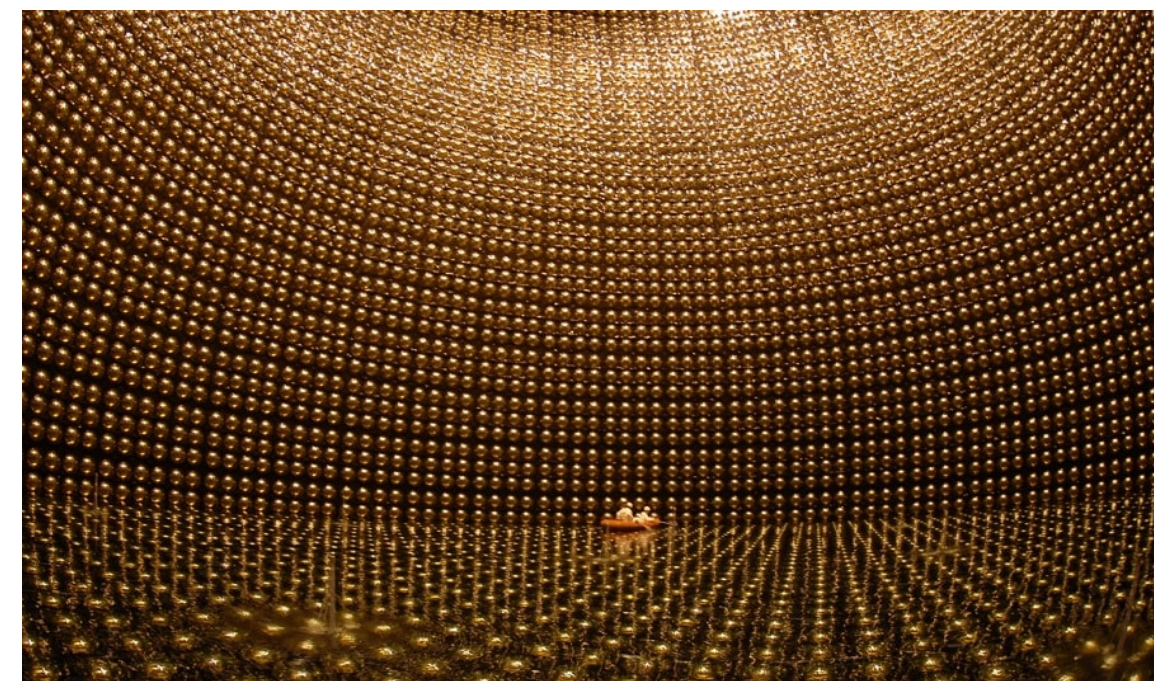
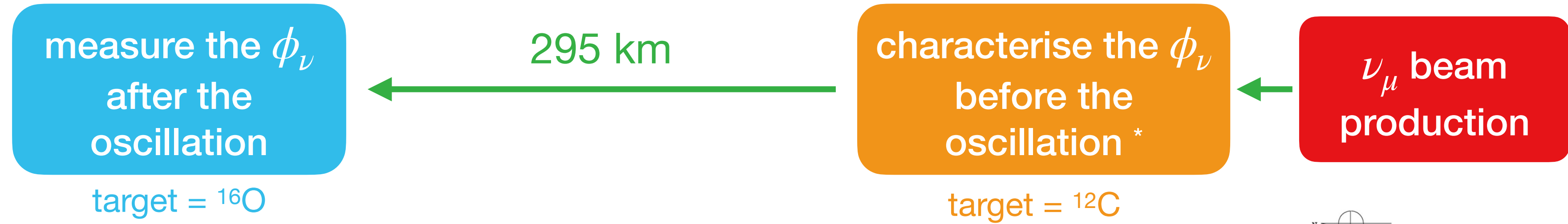
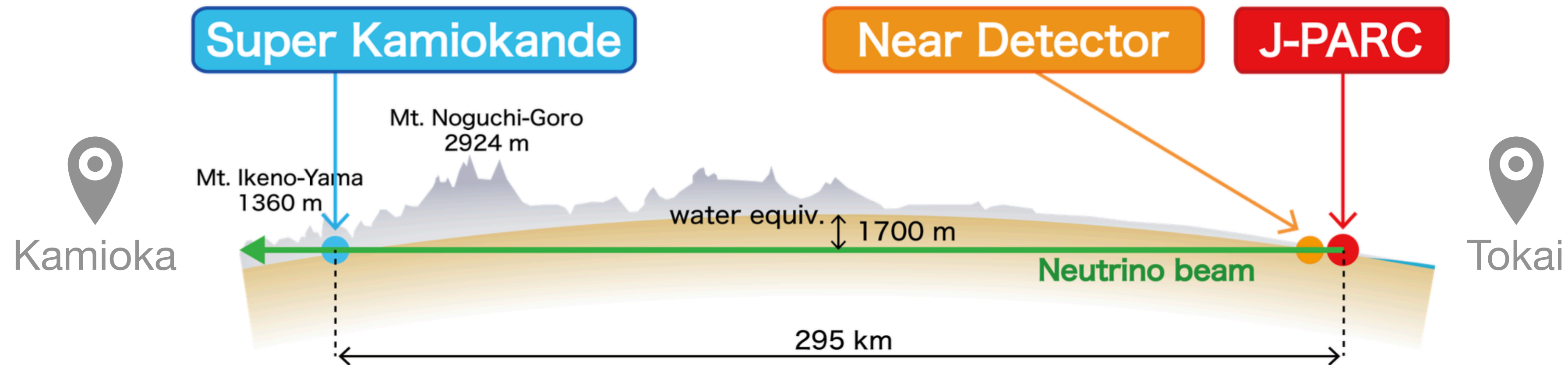
- **CC0 π 1p cross section** analysis:
 - looking at the **interactions** in the **gas** of the HA-TPC and vertical TPCs
 - project already started by Lukas Koch (still in T2K in Mainz)
- experiences and ED points:
 - 10 h formations d'ouverture
 - attend the 2 mandatory MOOCs
- starting writing the thesis (from the 2 on going papers)

CC0 π 1p interactions in the gas of the T2K TPCs

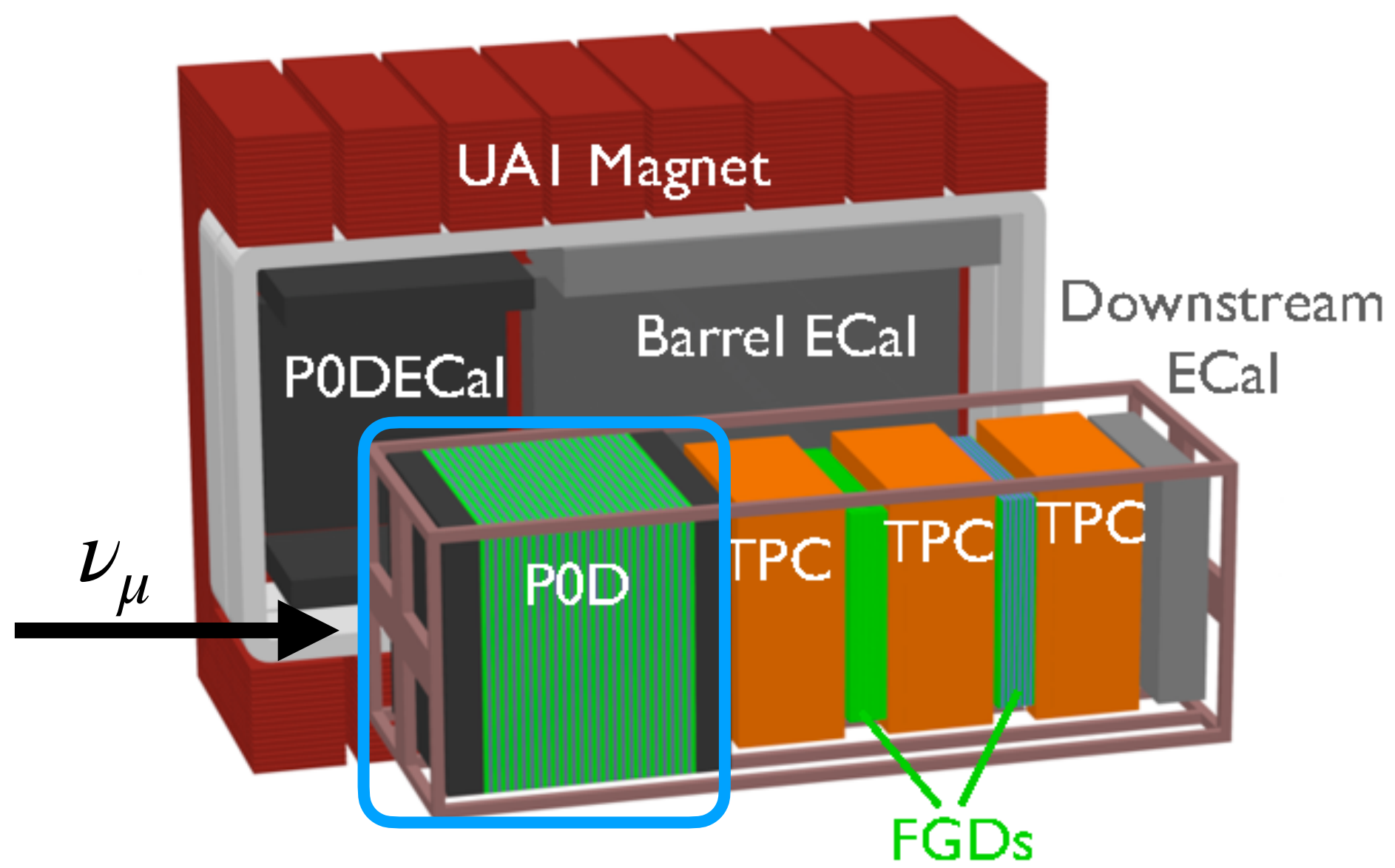
the T2K Experiment

a long-baseline oscillation neutrino experiment

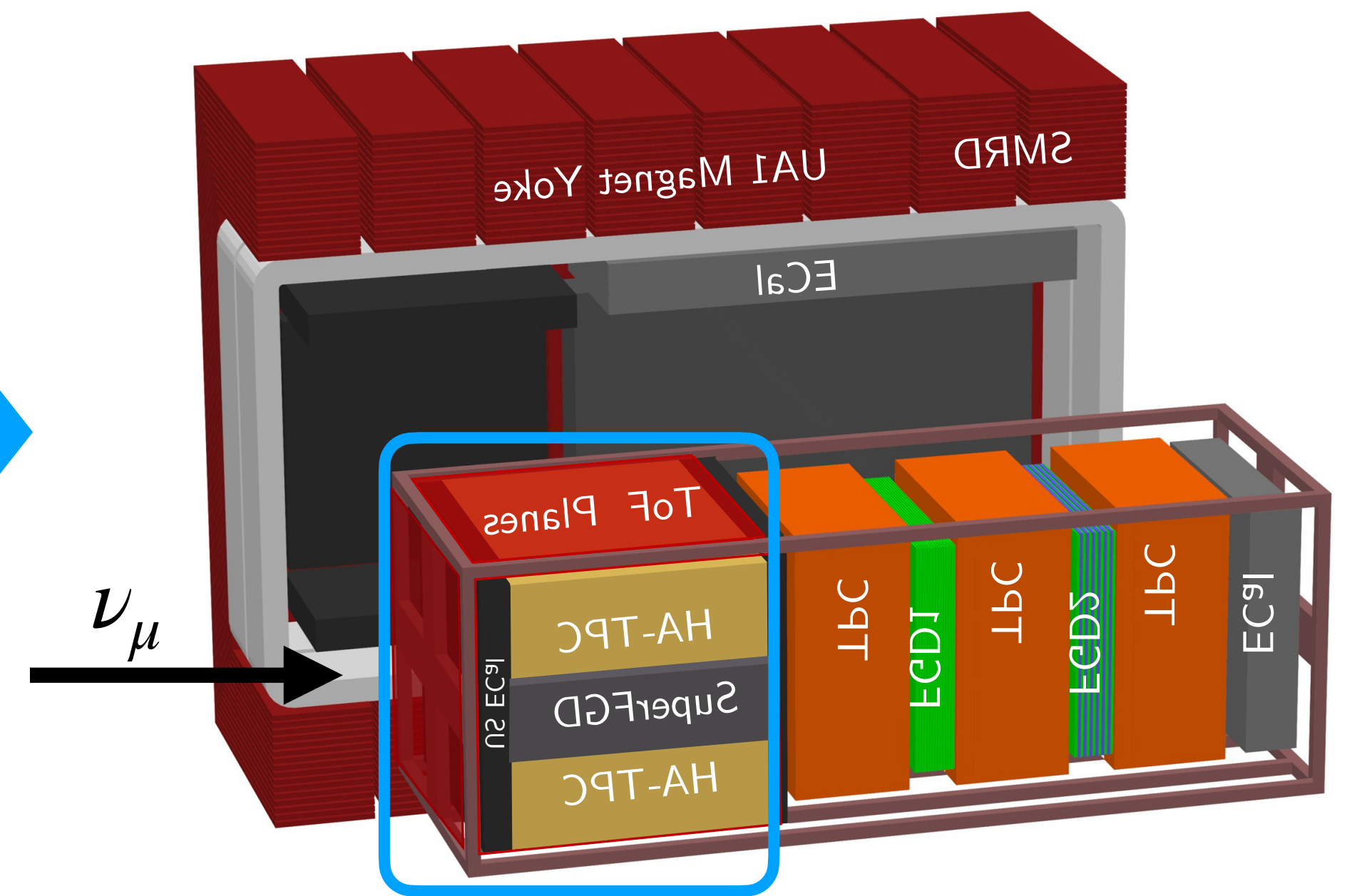
*with the help of NA61/SHINE experiment @ CERN



the ND280 upgrade



ND280 upgrade

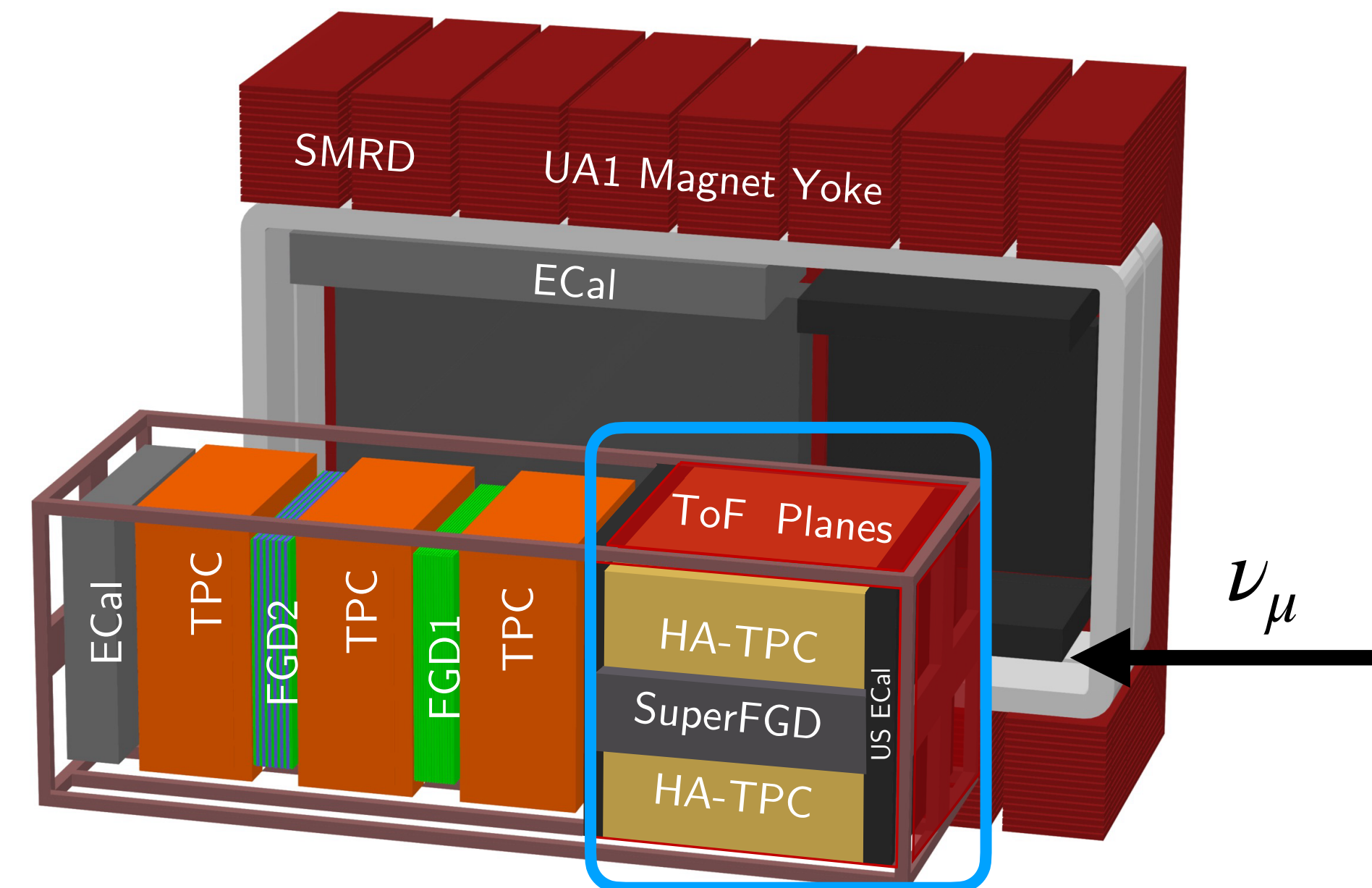
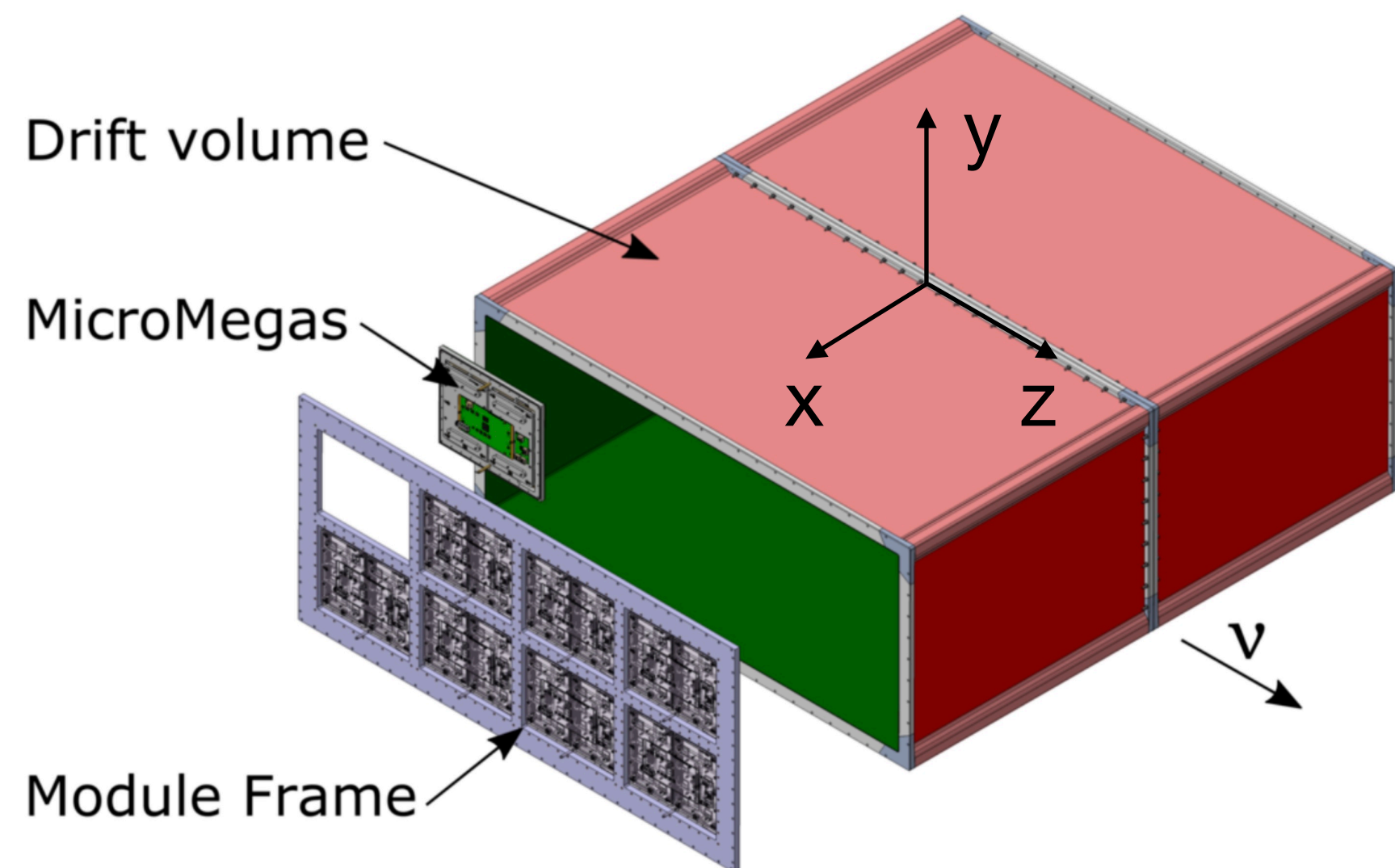


the ND280 upgrade

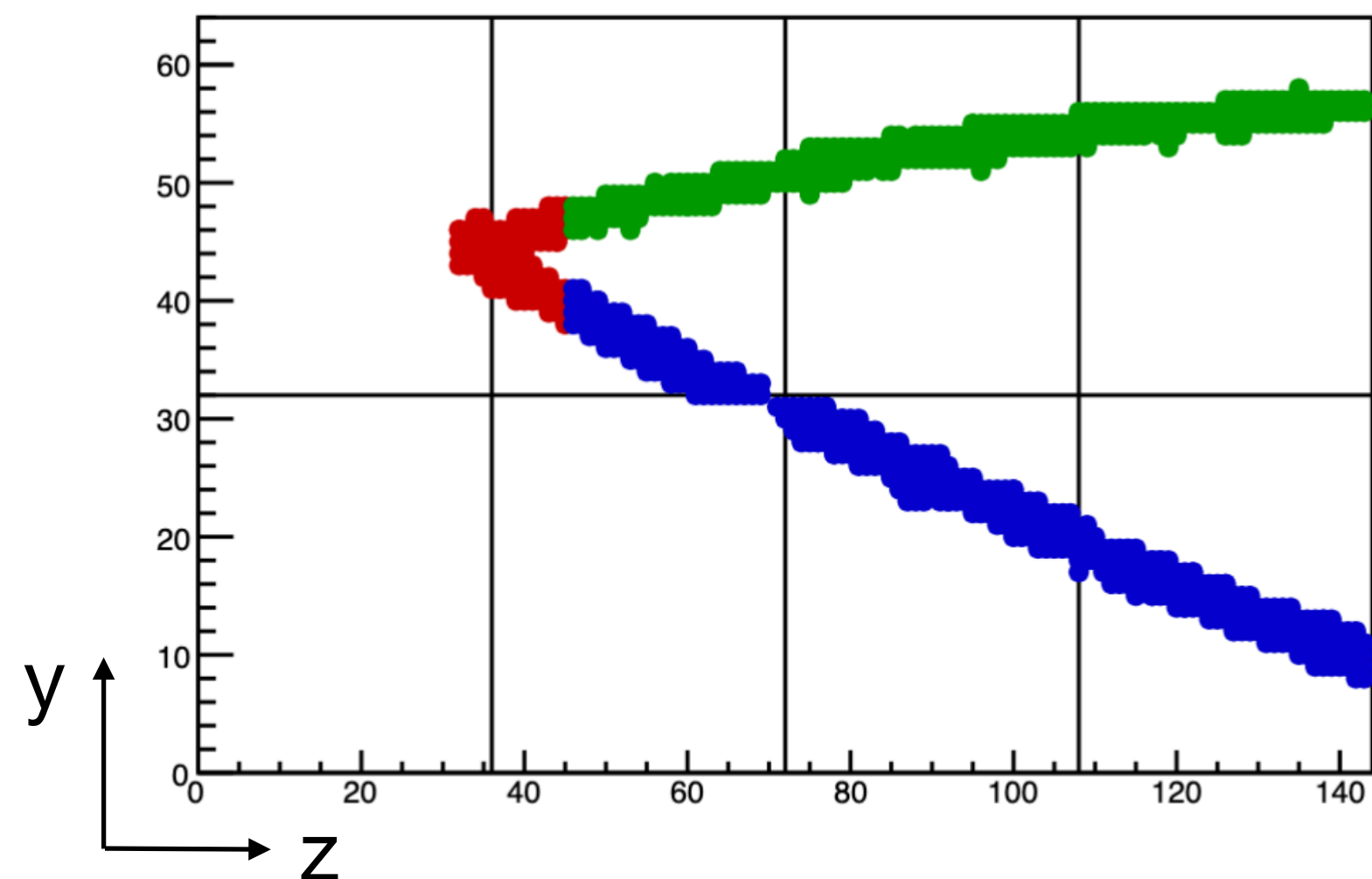


- **reduce** the ~ 400 MeV/c **reconstruction momentum threshold** and **increase** the interaction **probability**
- **reproduce** the 4π **angular acceptance** of the far detector

the HA-TPCs of the ND280 upgrade



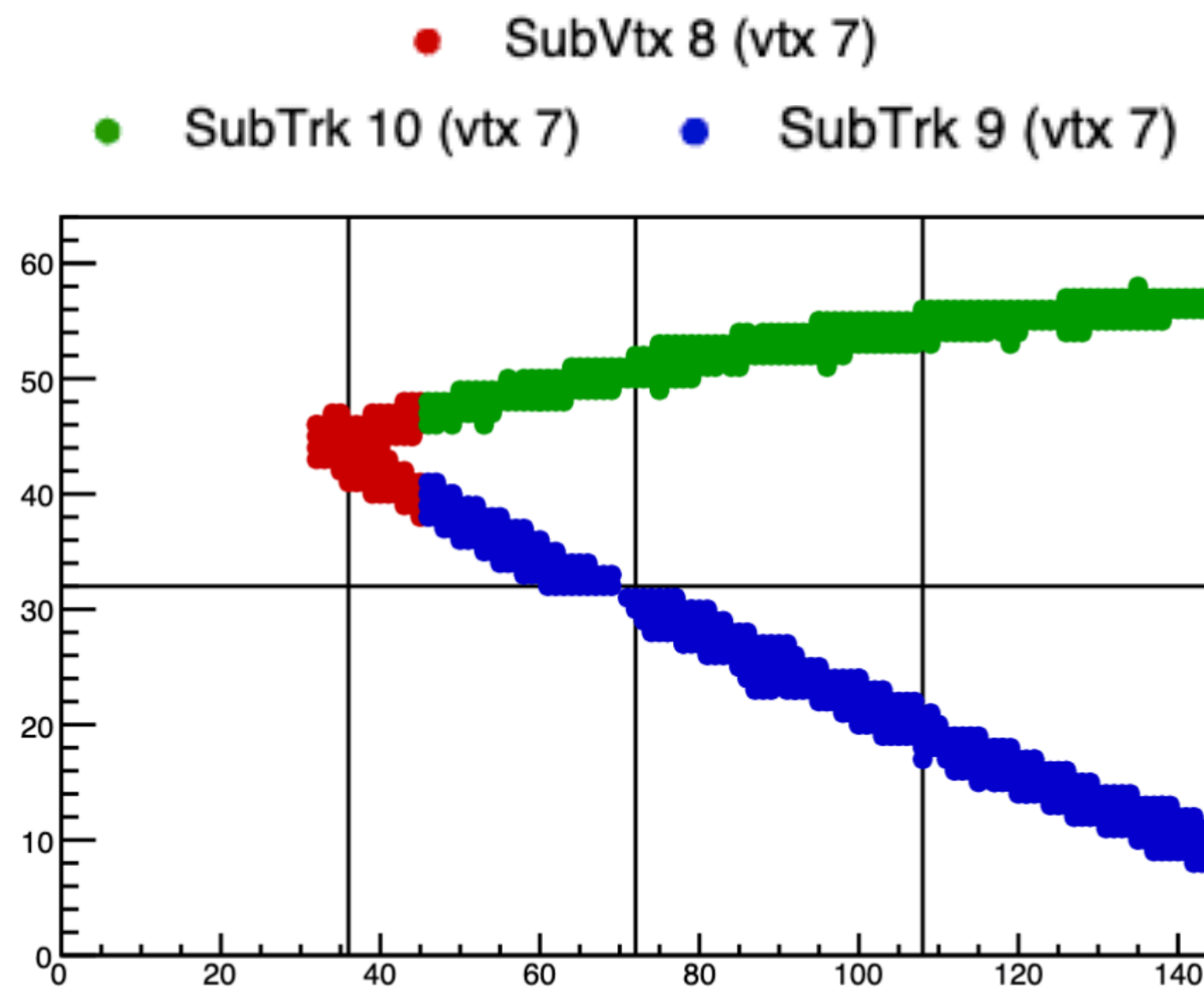
Endplate 3



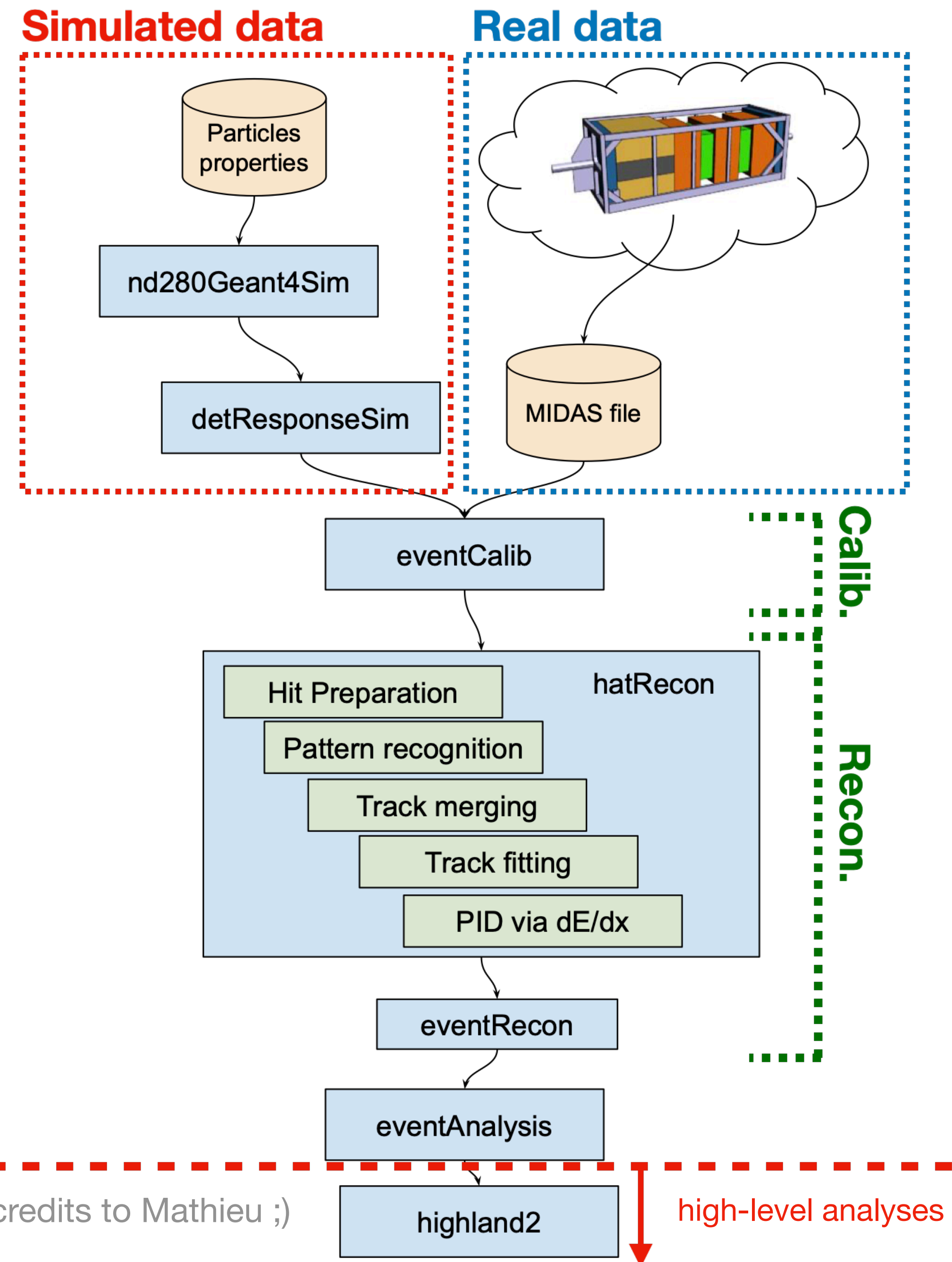
- 2 HATs with 2 endplate each
- each endplate has 8 MicroMegas modules (in a 4x2 structure)
- on the endplate plane we have a 2D reconstruction, the 3rd coordinate comes from the drift time

introduction to the project

- analysis of **neutrinos interactions** in the **gas** of the HATs (vTPCs) supervised by Claudio
- **CC0 π 1p** channel: **1 p** and **1 μ** in the final state
- did a Monte Carlo simulation with **1 p** and **1 μ** starting from the **same vertex** in the **top HAT**



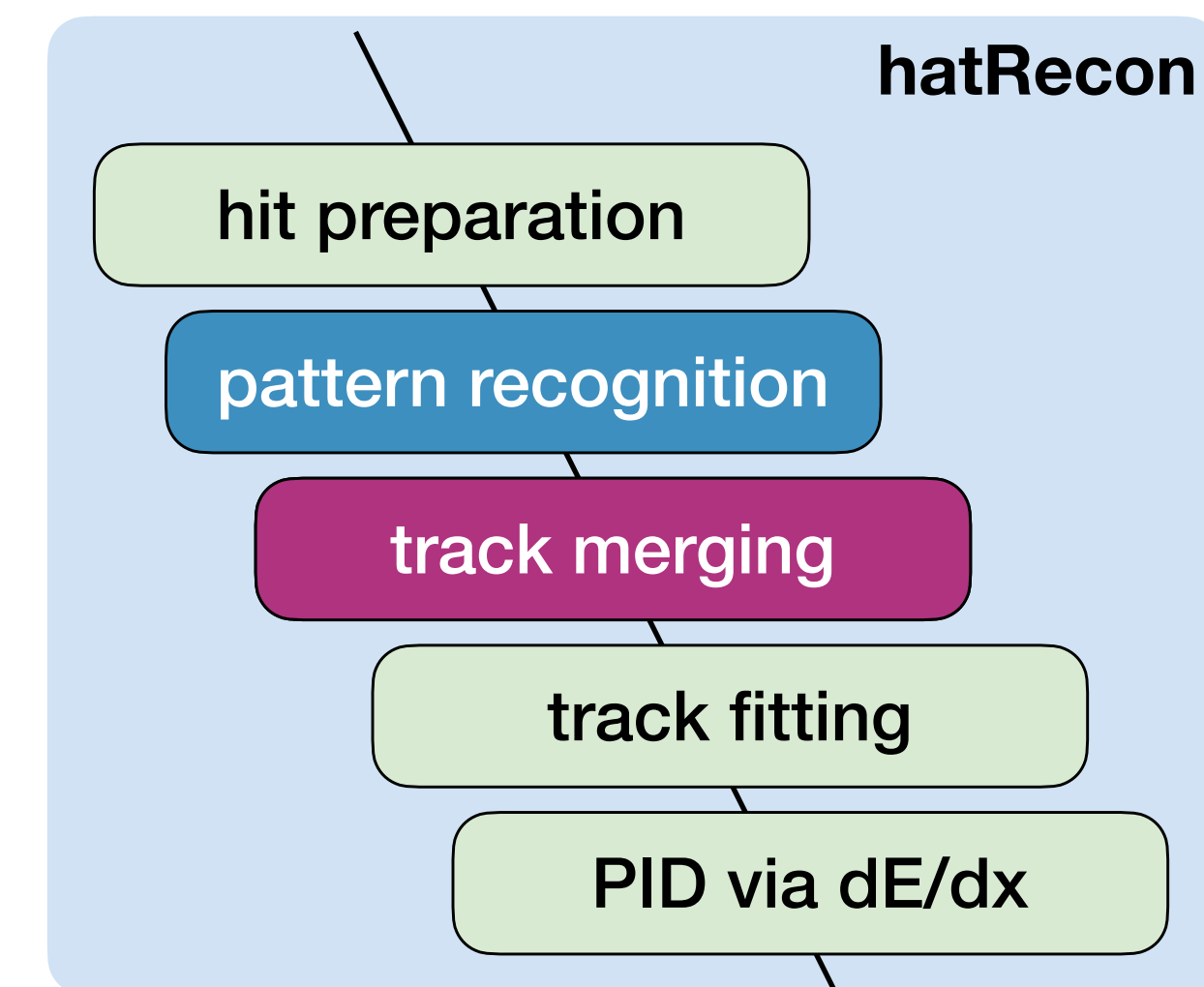
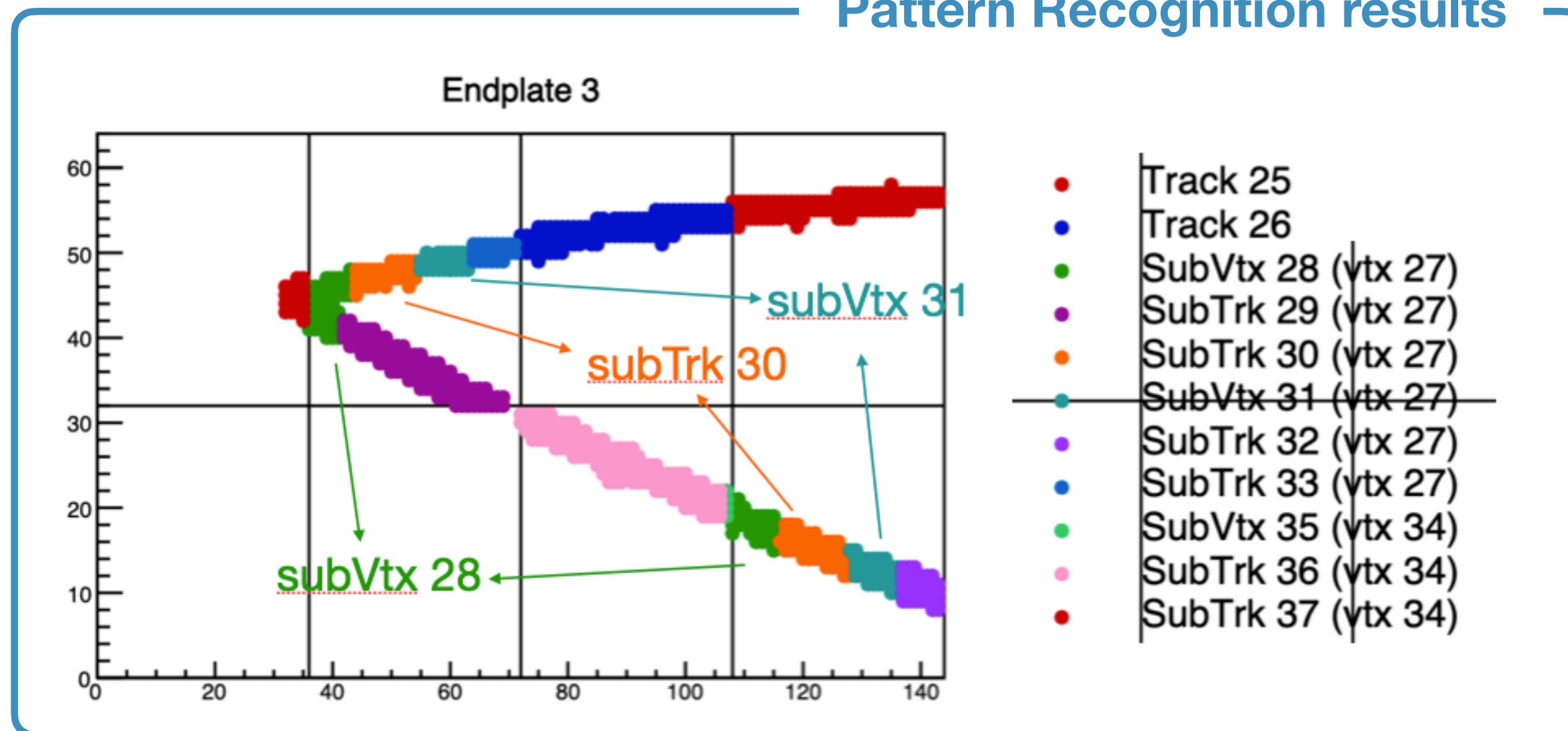
vertex 7
 — subvertex 8
 — subtrack 9
 — subtrack 10



the starting point in hatRecon

before the bug fix

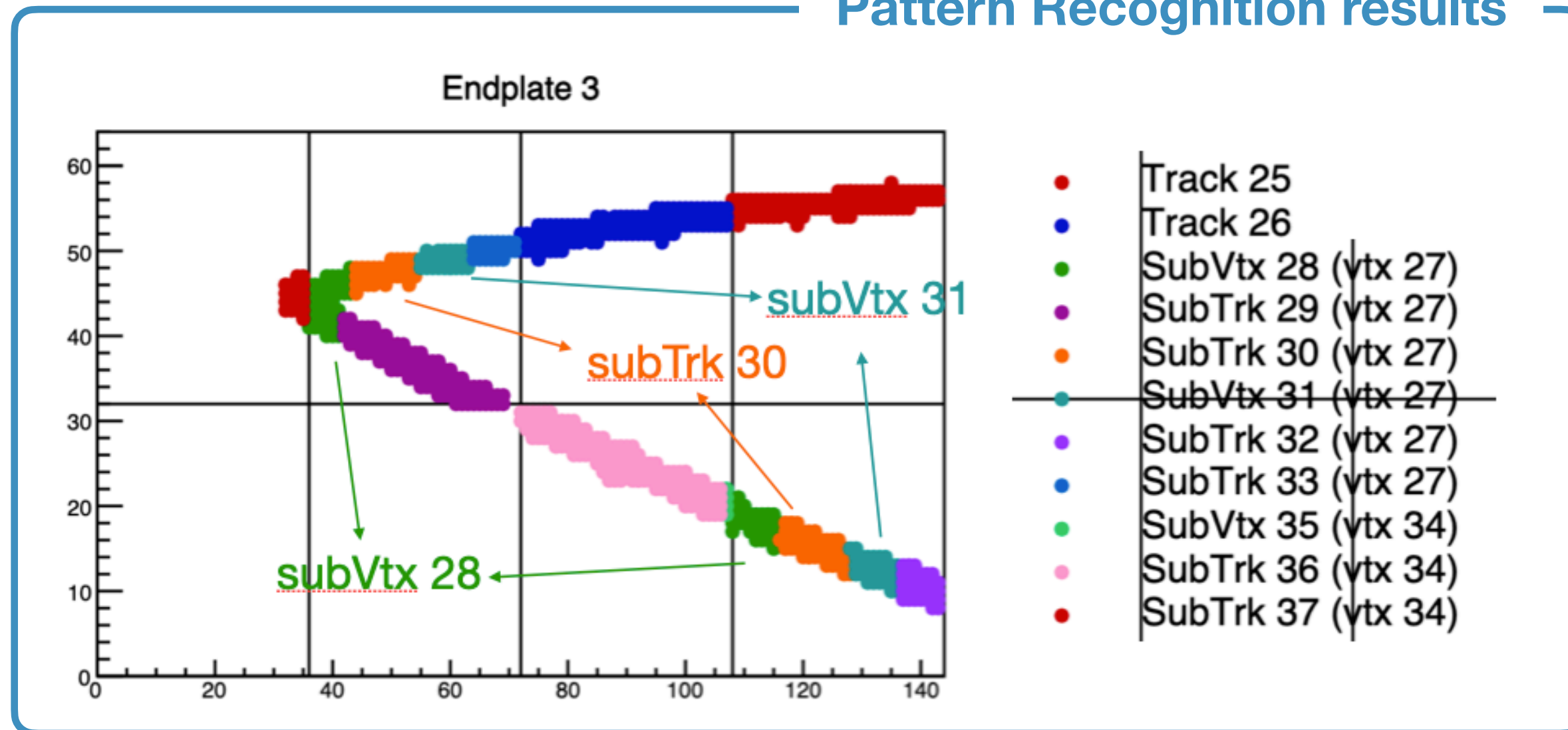
Pattern Recognition results



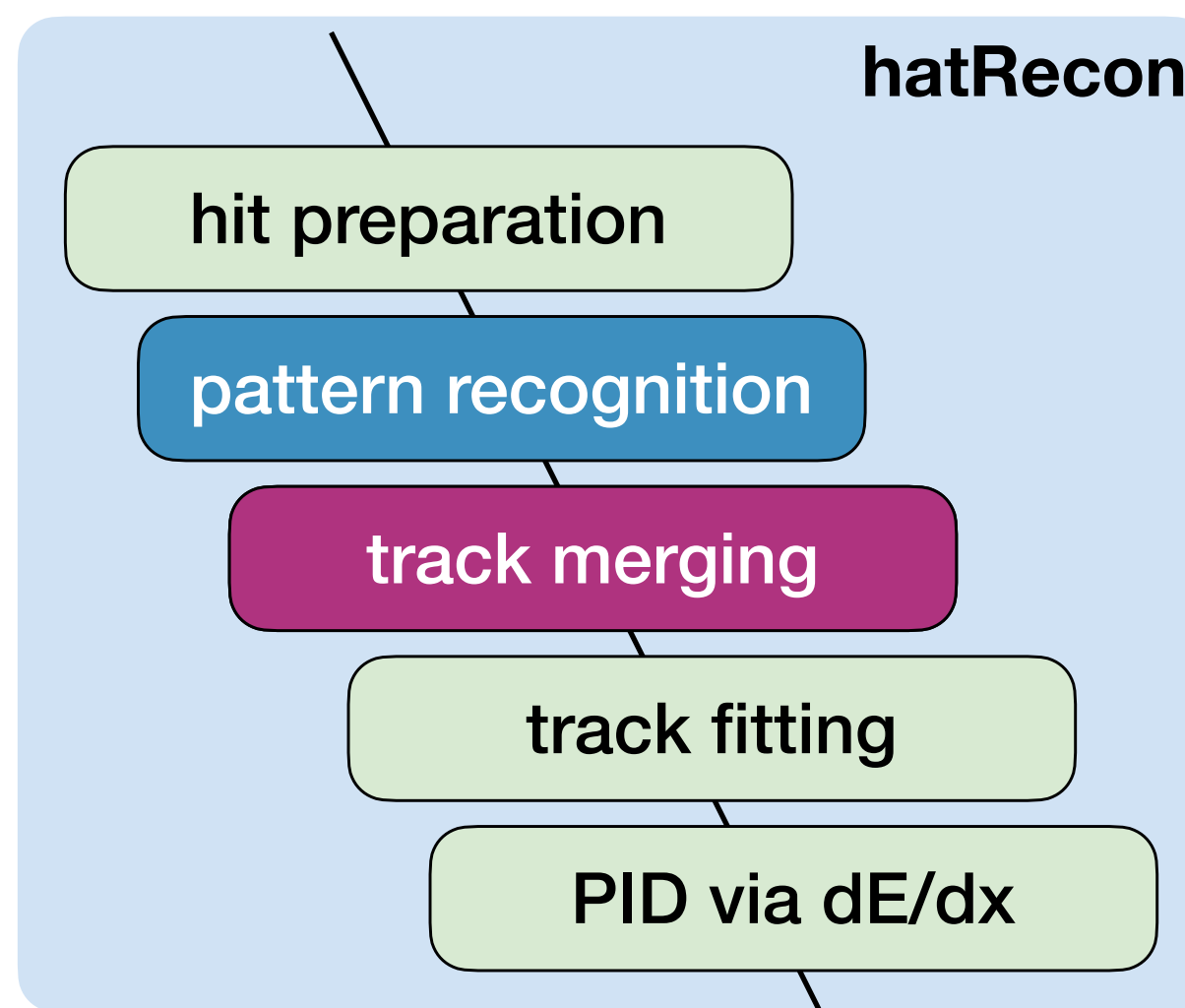
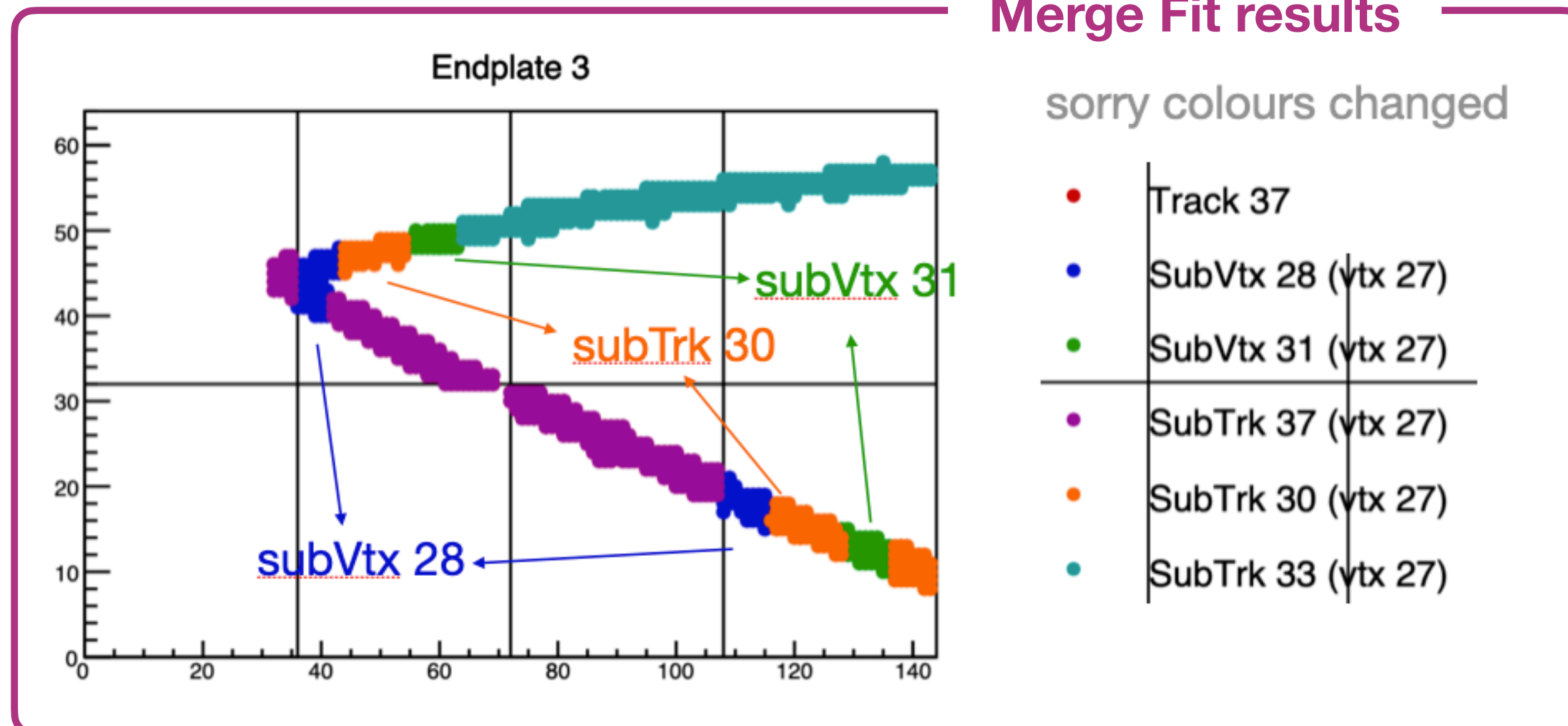
the starting point in hatRecon

before the bug fix

Pattern Recognition results



Merge Fit results

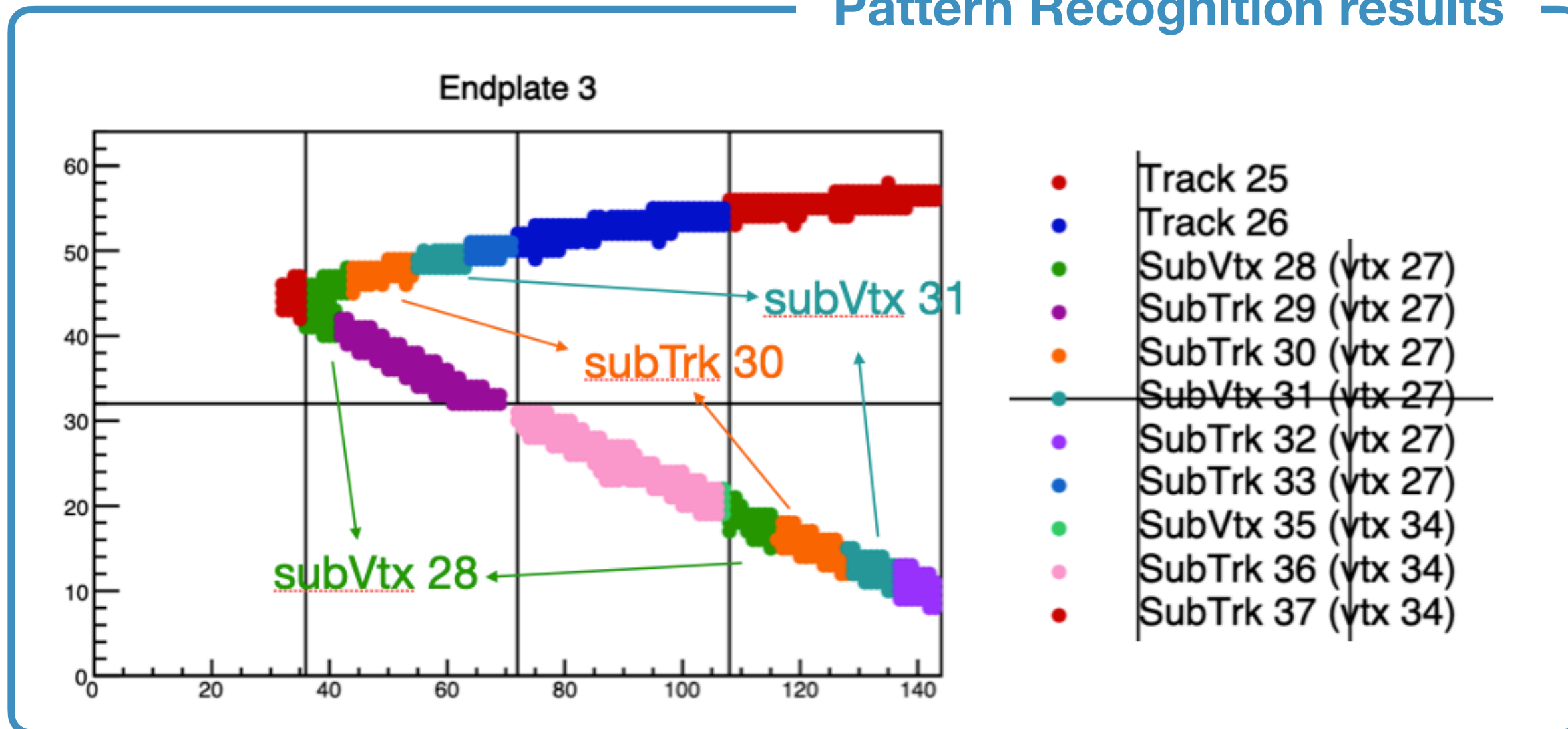


before the bug fix

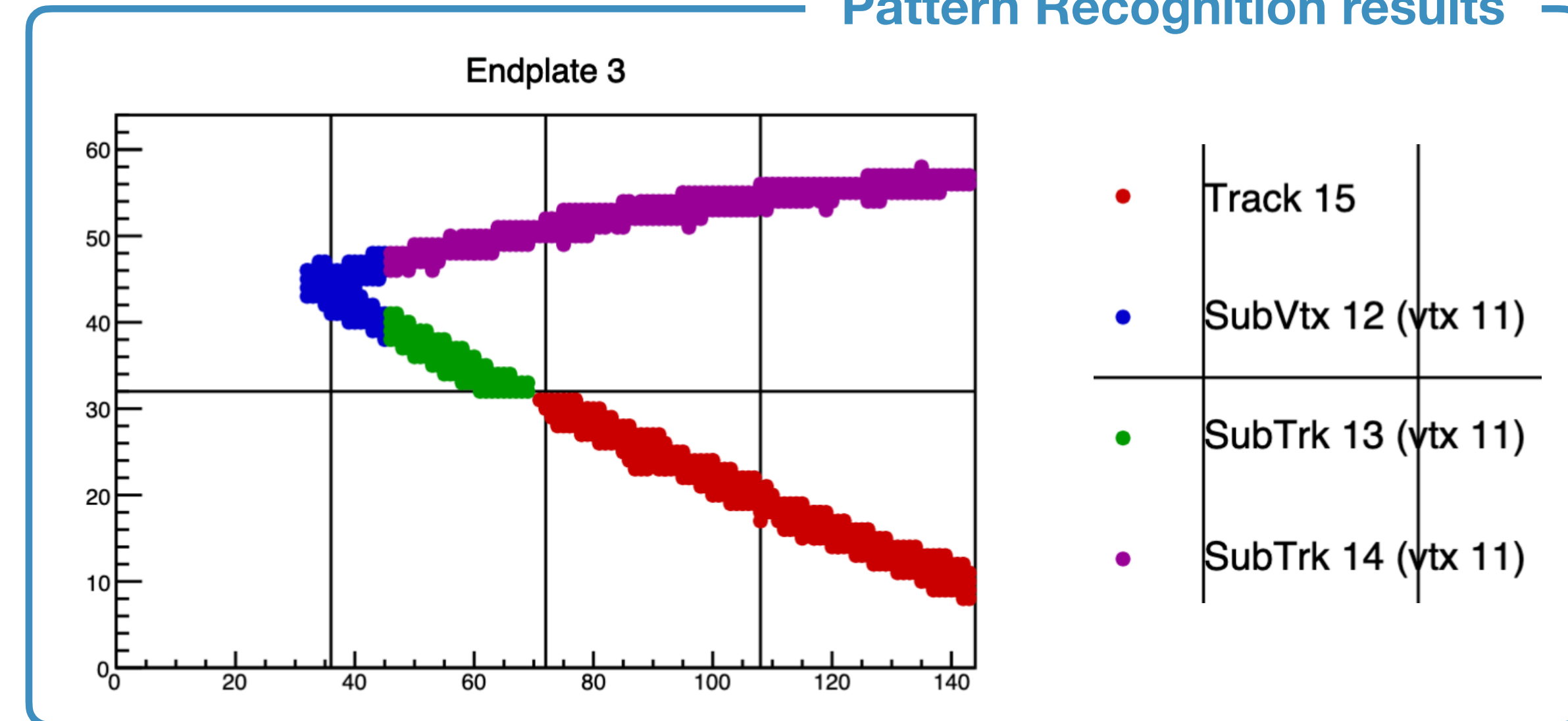
... and ...

after the bug fix

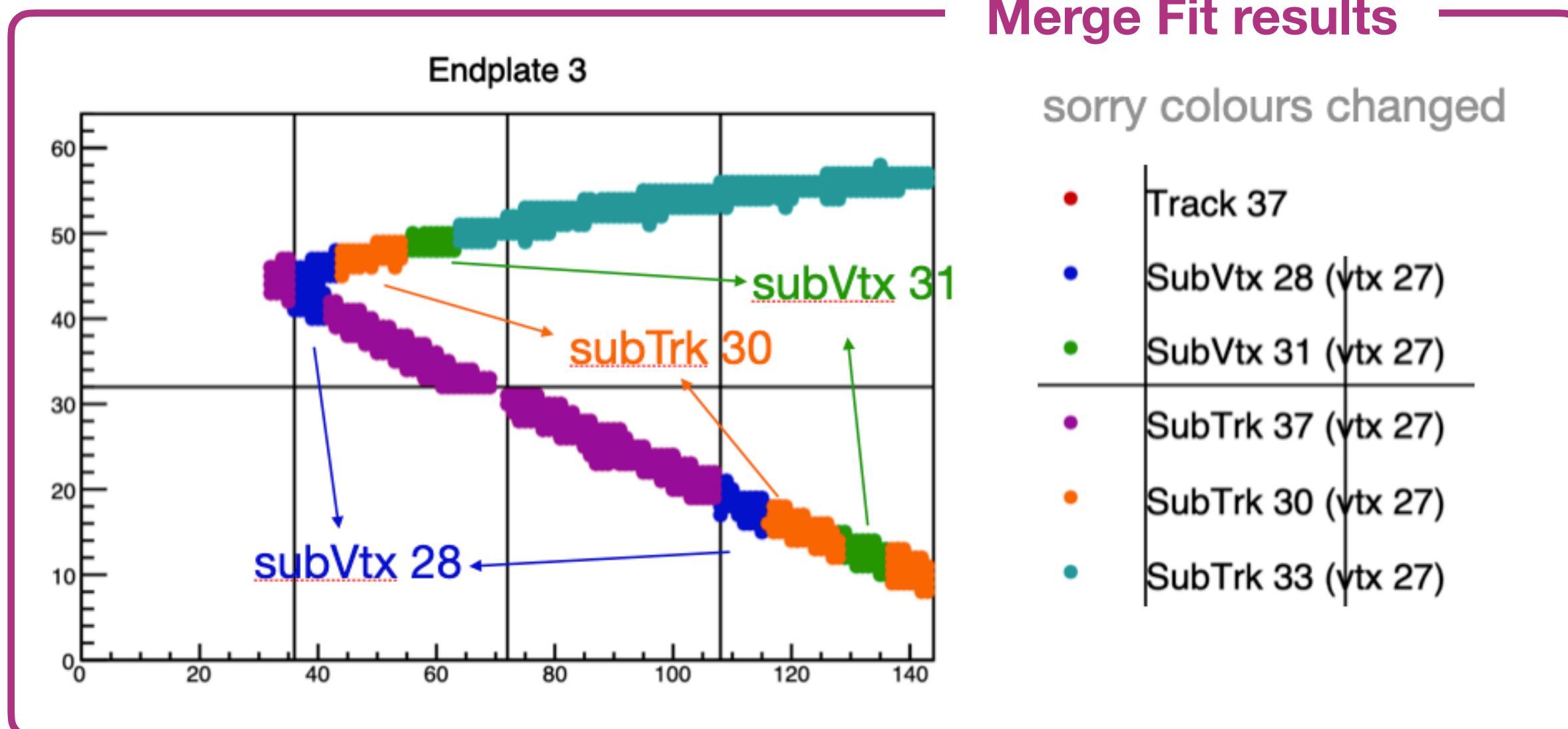
Pattern Recognition results



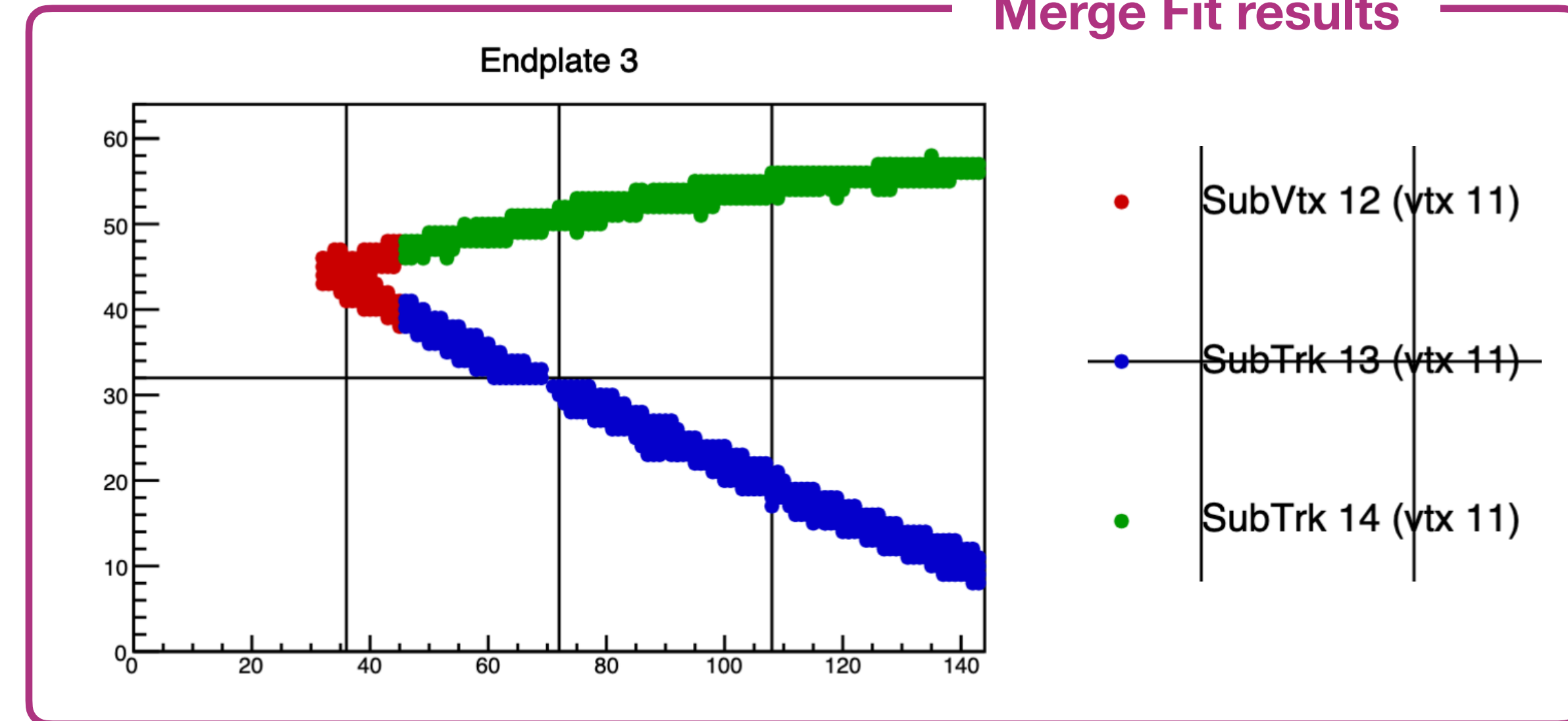
Pattern Recognition results



Merge Fit results



Merge Fit results

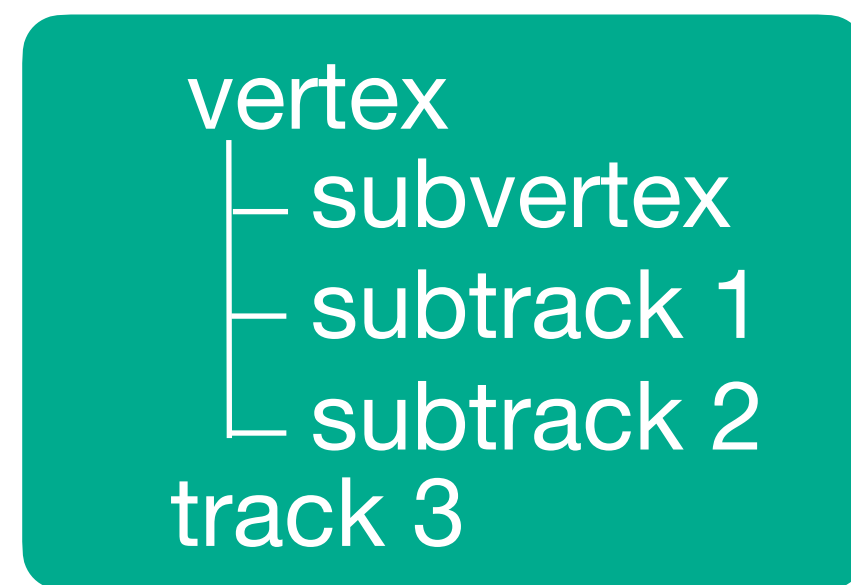


today's status

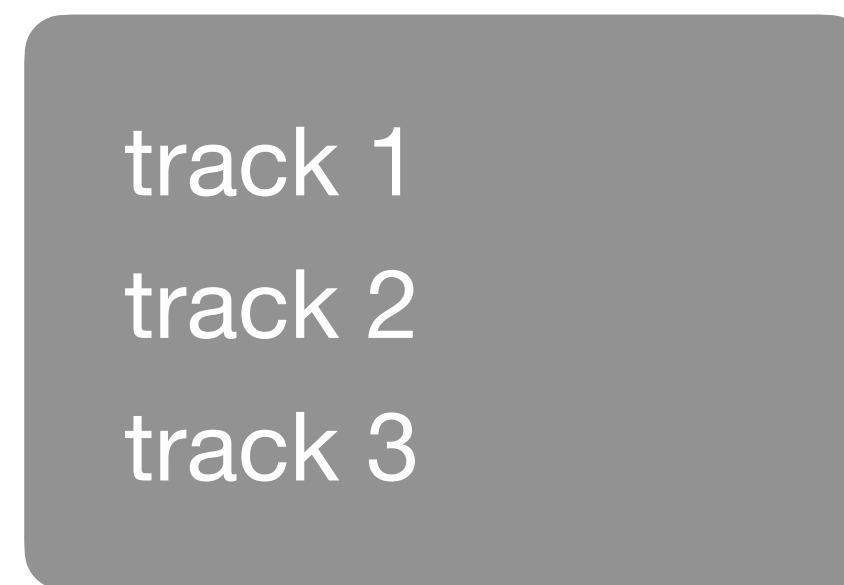
in the official release so far:

- we **do not save** the **actual hierarchy** after pattern recognition:

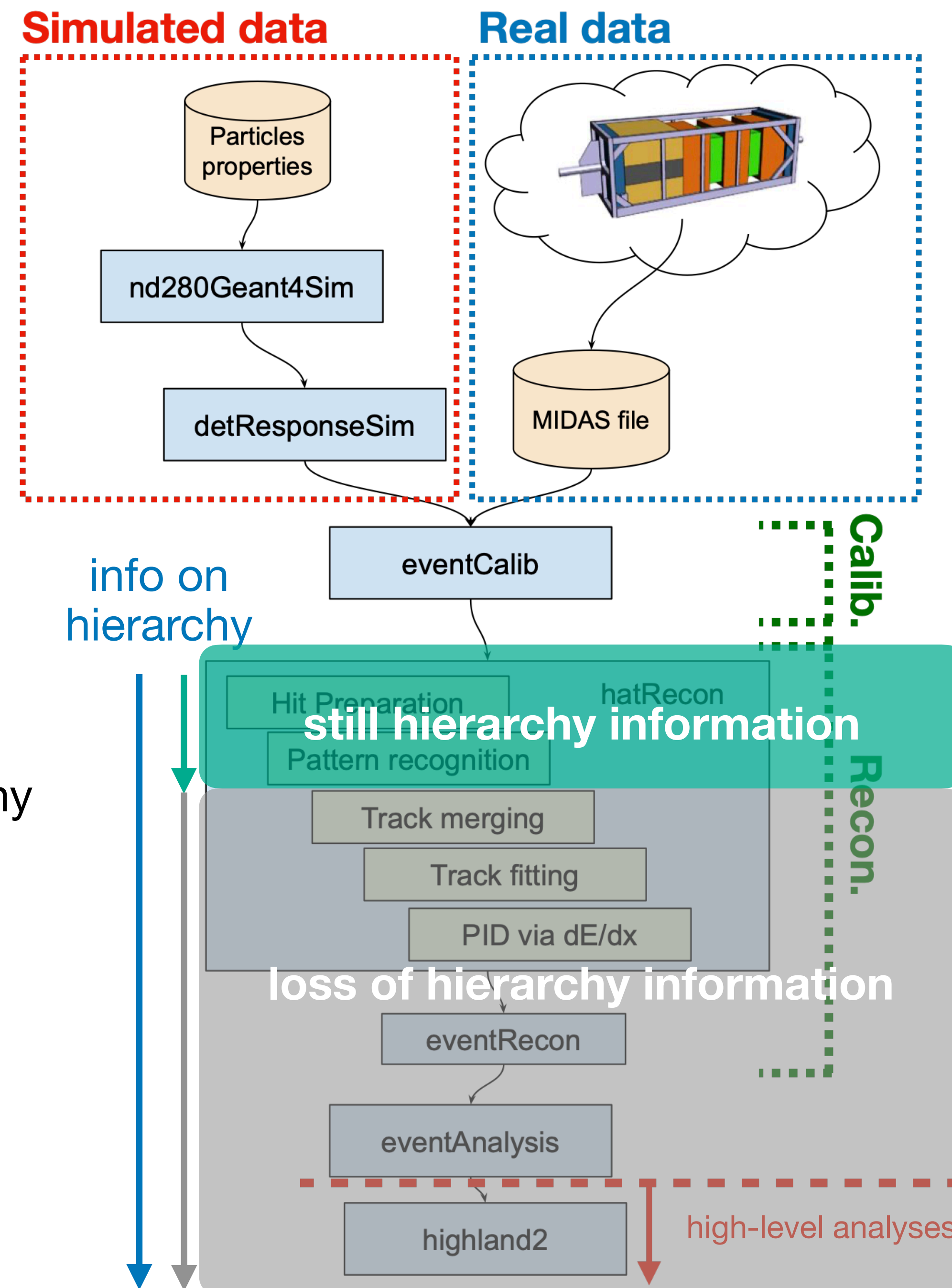
until pattern recognition



after pattern recognition



- but for our analysis we want to **keep track** of the actual hierarchy
- I **propagated** the **info** through all hatRecon and on the global reconstruction (work in progress)

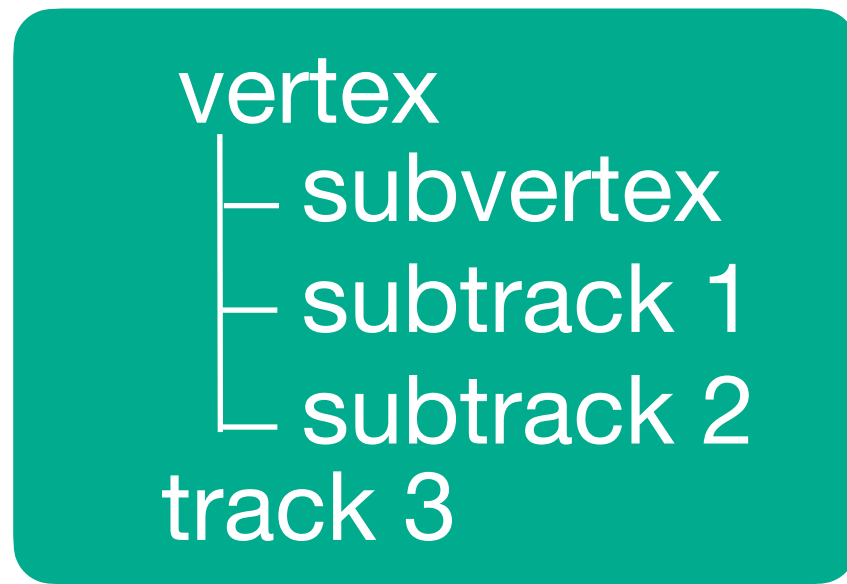


today's status

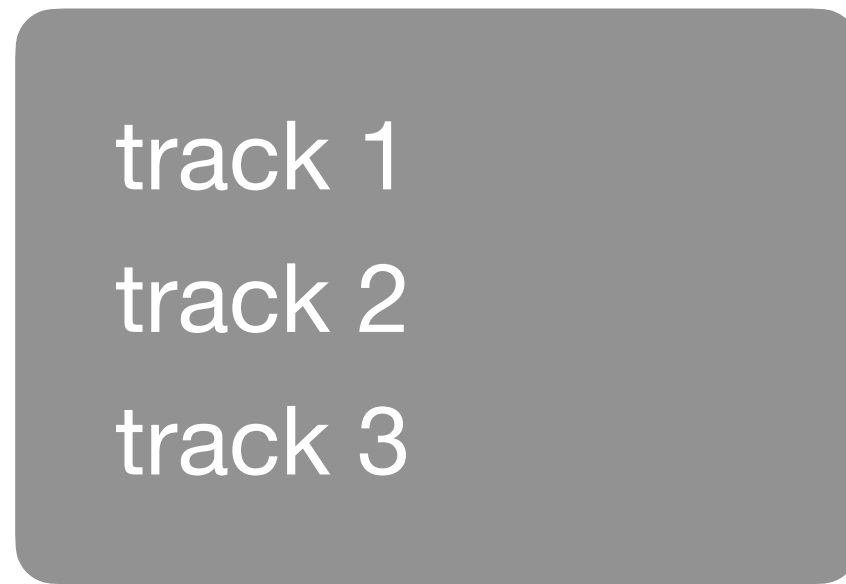
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until pattern recognition

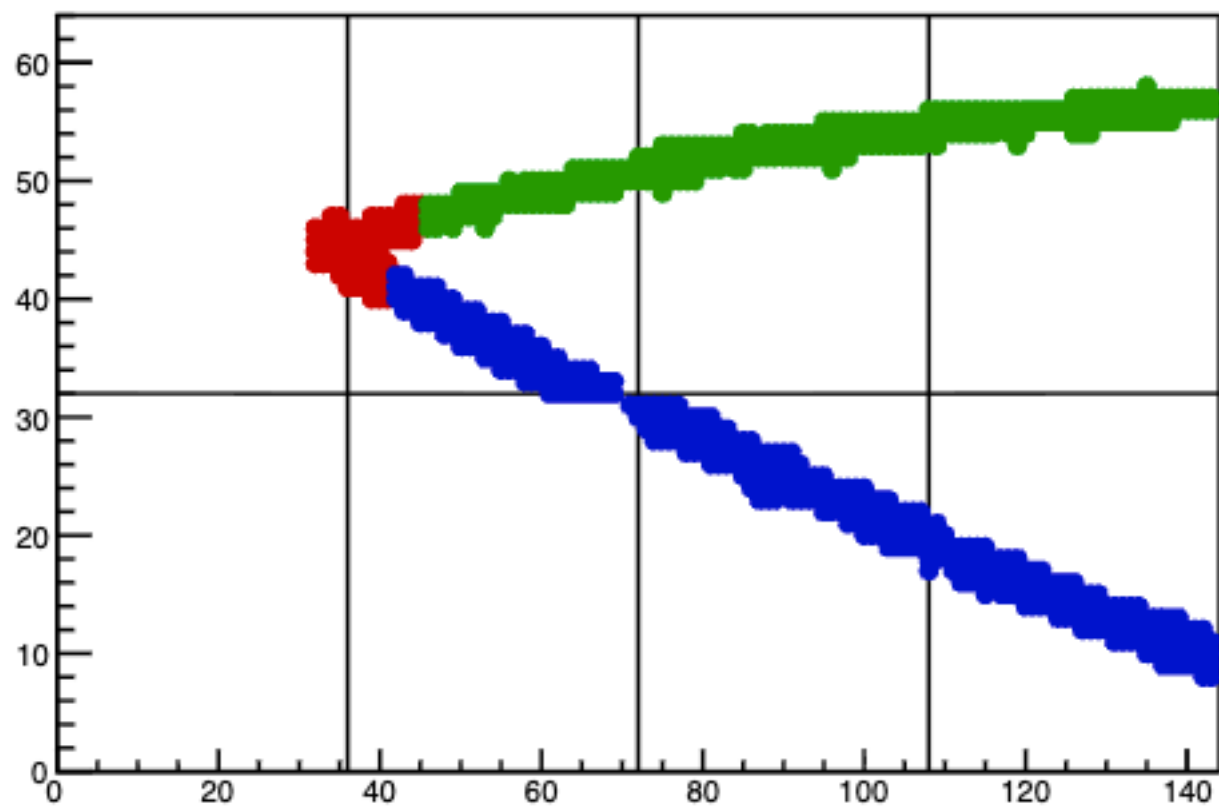


after pattern recognition



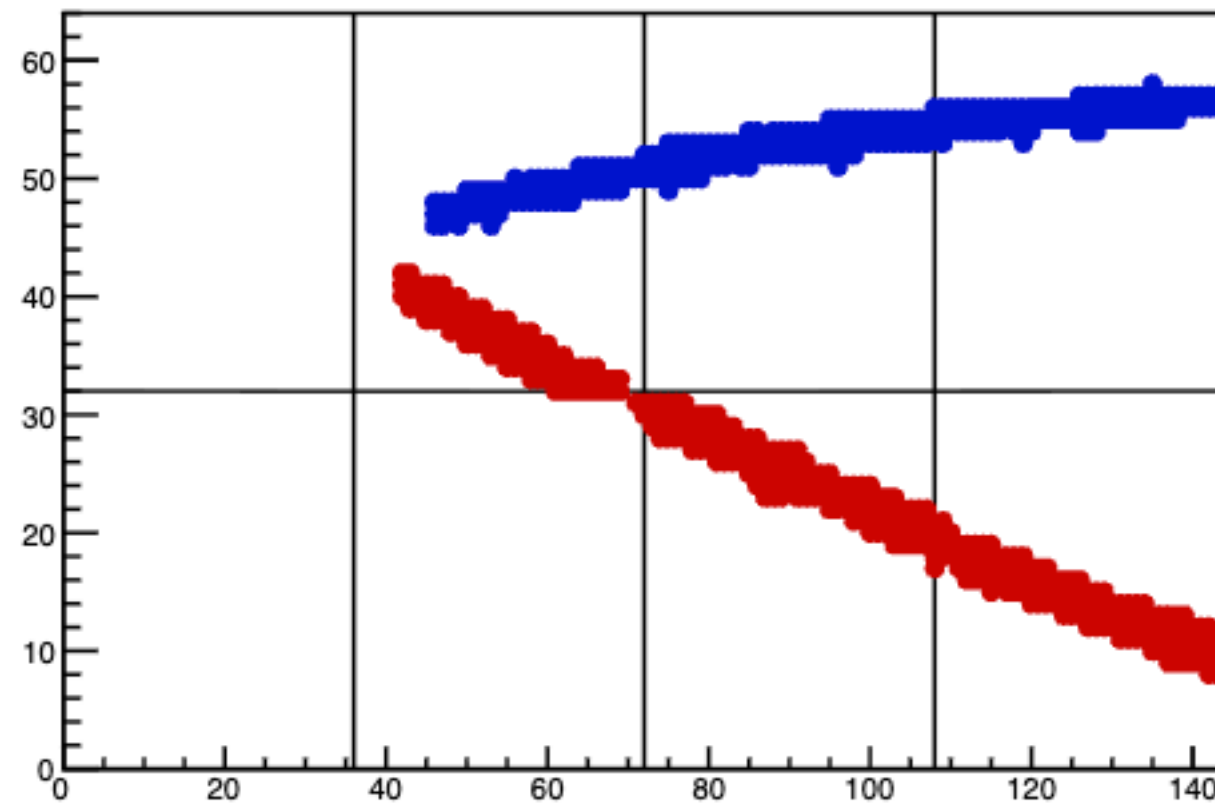
Merge Fit results (my work)

- SubTrk 10 (vtx 7)
- SubTrk 9 (vtx 7)
- SubVtx 8 (vtx 7)



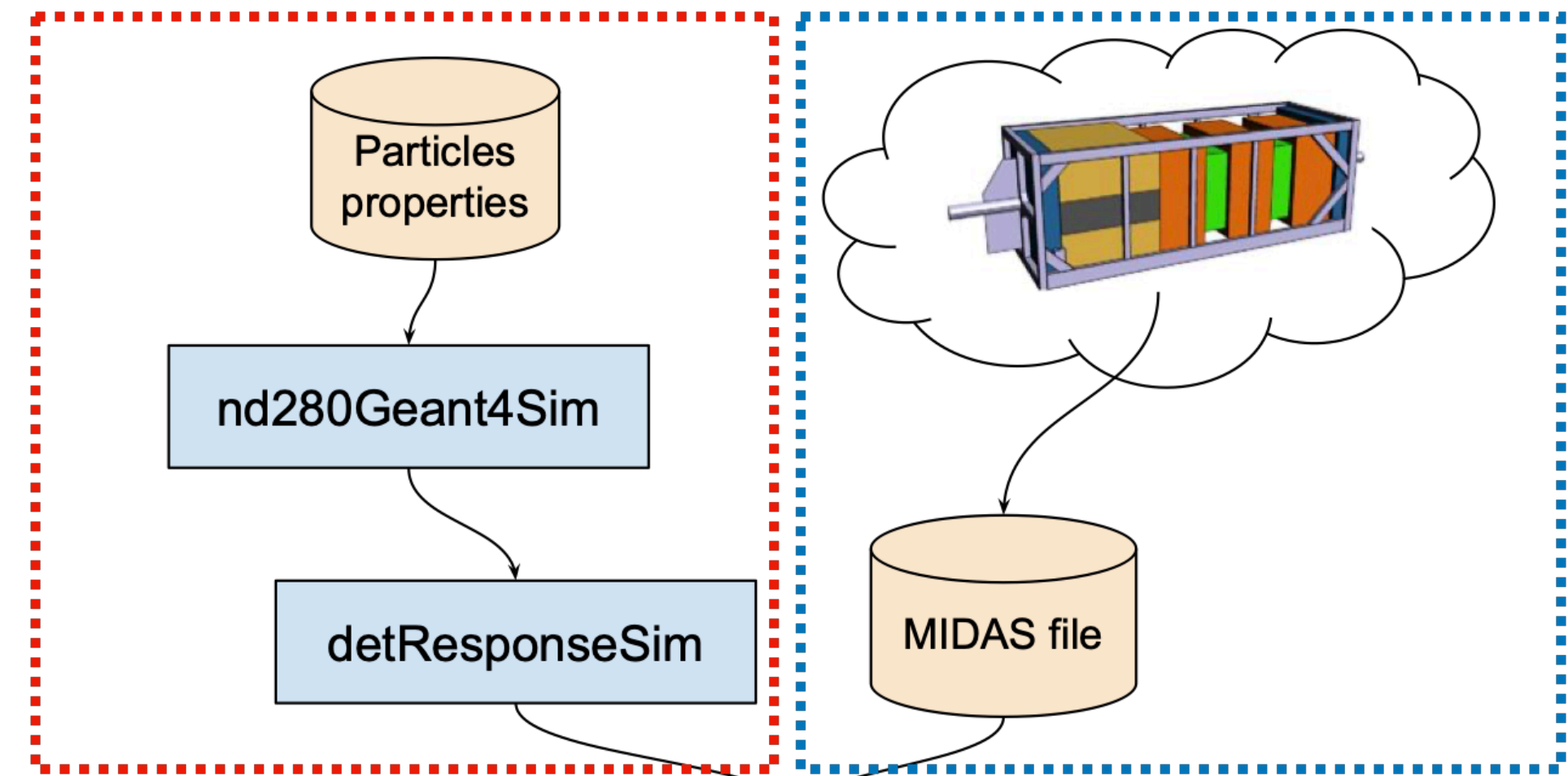
Merge Fit results (official release)

- Track 0
- Track 1

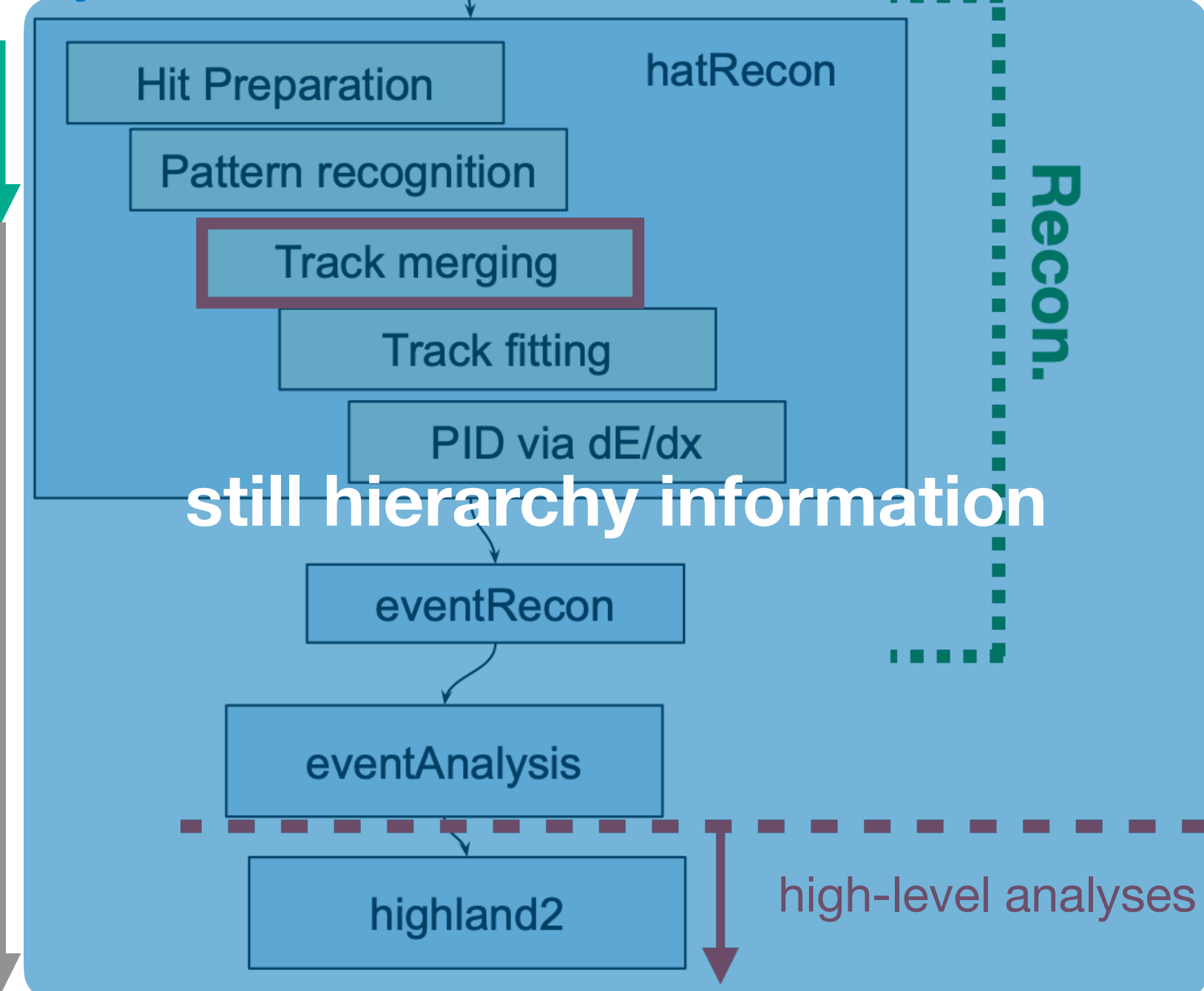


Simulated data

Real data



info on hierarchy

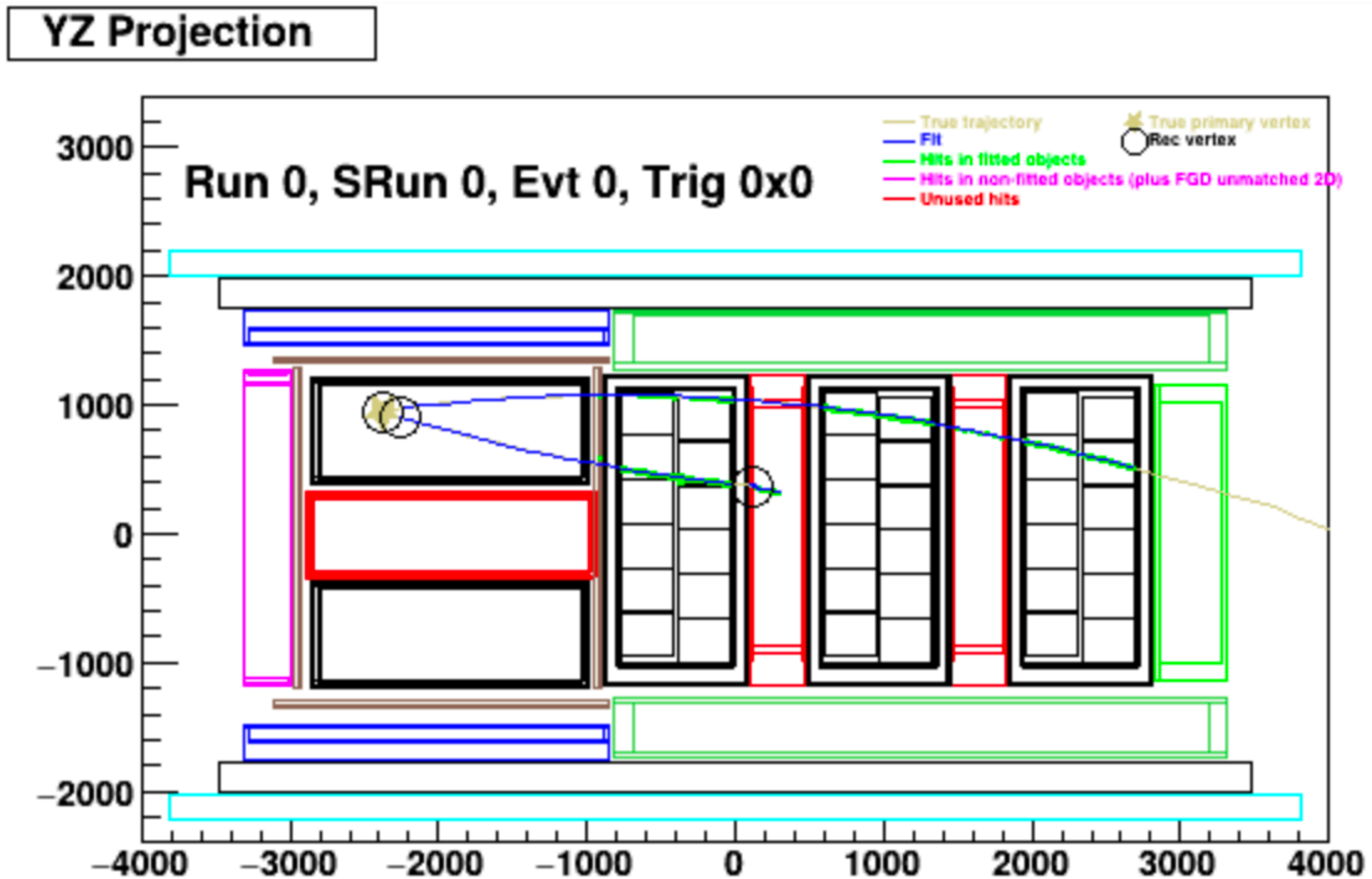


still hierarchy information

today's status

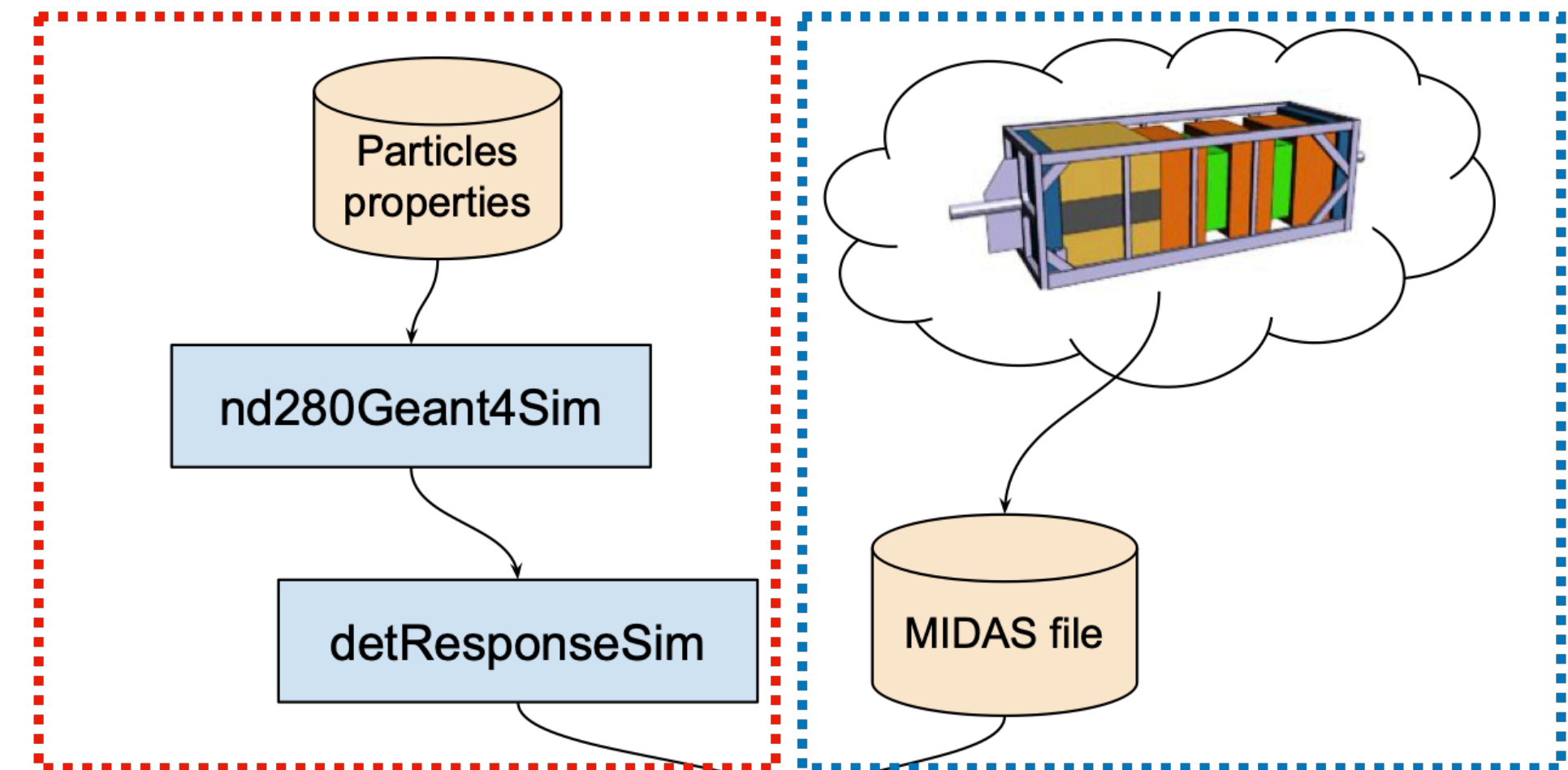
eventRecon results

we are capable of seeing the **subtracks** in the **global reconstruction!**

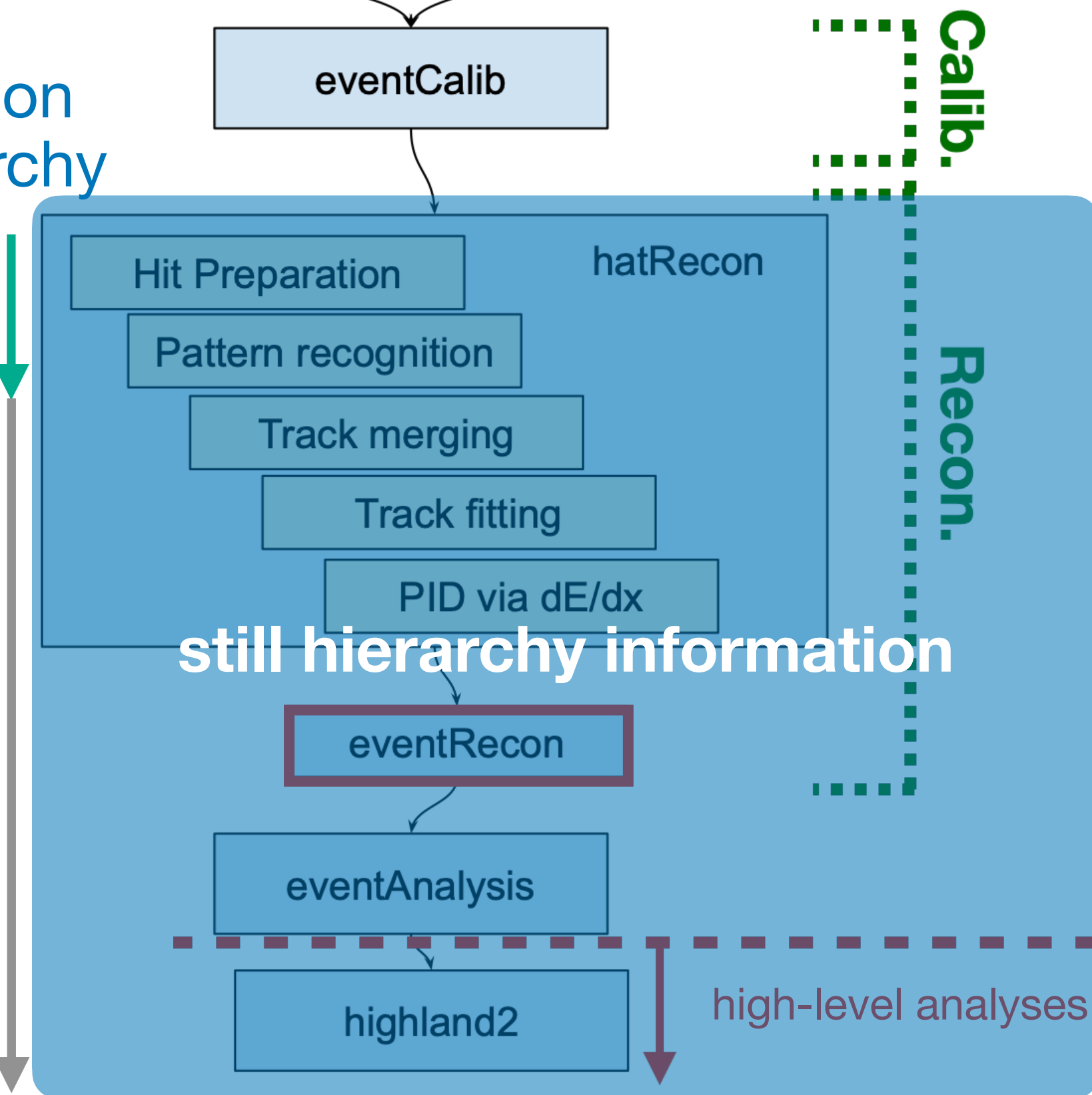


Simulated data

Real data



info on hierarchy



still hierarchy information

ED points, conferences and experiences

points de l'école doctorale

slide from 2nd year CSI

[link to the indico of 2 CSI](#)

fait

en cours

planifié

obligatoire

Formation	Duration	PIF category
Cours de français	30 h	transverses
MOOC* intégrité scientifique	15 h	transverses
MOOC science ouverte	15 h	transverses
NuSTEC summer school	40 h	scientifiques
Vacations à l'UPC	24 h	-
-	10 h	d'ouverture

transverses
60 h → 40 h

scientifiques
40 h

d'ouverture
au moins 10 h

À faire :

- formation d'ouverture (10 h)
- MOOC sur intégrité scientifique (~fait)
- MOOC science ouverte (à commencer)

*MOOC = Massive Open Online Courses

points de l'école doctorale

done all the formations

fait

en cours

planifié

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transverses
60 h → 40 h

scientifiques
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d'ouverture
au moins 10 h

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conferences and experiences

1st year

done

planned

	aim	when	contribution
CERN	start Martini's model implementation	February 2024	:)
JPARC, Tokai - Japan	shifts + CM*	March 2024	2 preliminary talks
NuSTEC summer school - CERN	XSec summer school	June 2024	:)
Neutrino 2024 - Milano	conference	June 2024	poster about Martini model implementation into GENIE
T2K workshop - CERN	CM*	July 2024	plenary talk on HA-TPCs

*CM = Collaboration Meeting

conferences and experiences

2nd year

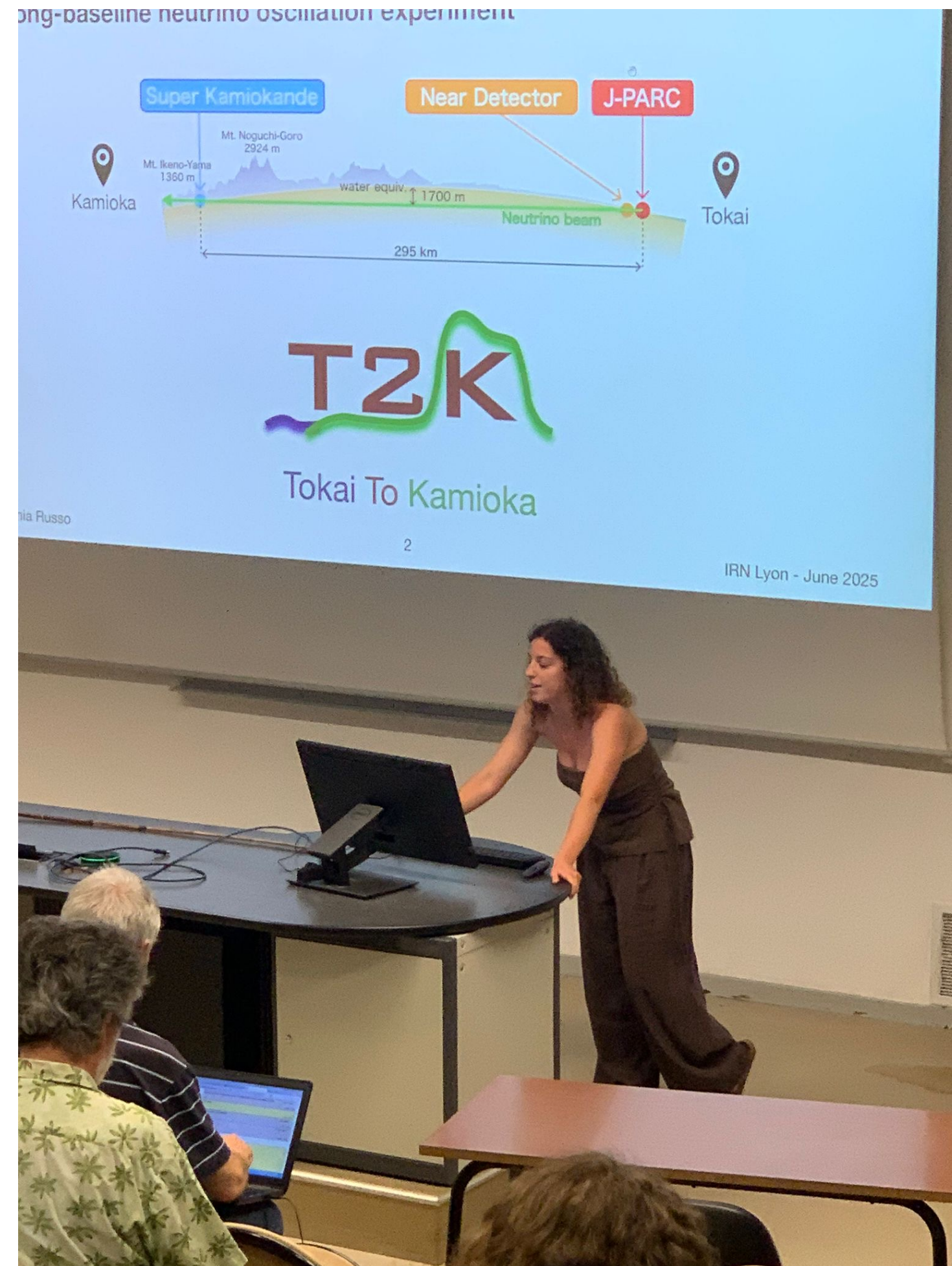
done

planned

	aim	when	contribution
JPARC - Tokai, Japan	TPC expert shifts + CM	November 2024	2 preliminary talks
JPARC - Tokai, Japan	TPC expert shifts + CM	March 2025	1 preliminary talk
CERN	finalising Martini's model implementation	May 2025	-
IRN meeting - Lyon	conference	June 2025	talk on the HA-TPC
T2K workshop - CERN	CM	July 2025	talk on the HA-TPC
NuFact 2025 - Liverpool	conference	September 2025	parallel talk on GENIE paper
NuInt 2025 - Mainz	conference	October 2025	poster on GENIE paper

IRN June 2025 - Lyon ✓

talk on ND280 upgrade



NuInt 2025 - Mainz ✓

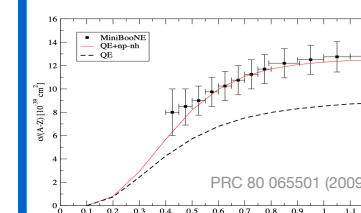
poster on Martini et al. implementation



Implementation of the Martini-Ericson-Chanfray-Marteau RPA-based (anti)neutrino cross-section model in the GENIE event generator

Lavinia Russo, Marco Martini, Stephen Dolan, Laura Munteanu, Boris Popov, Claudio Giganti based on arXiv: 2508.13939

The MARTINI-ERICSON-CHANFRAY-MARTEAU MODEL



Martini, Ericson, Chanfray and Marteau provided the explanation for the MiniBooNE CCQE-like cross section:

- MiniBooNE studied CCQE-like events **reconstructing only the leptonic part**
- Initial predictions that included only genuine CCQE showed a clear **mismatch** with the data
- Martini et al. **included** in the predictions the **npnh channel** — which leads to the same final state as genuine CCQE when considering only the leptonic part — achieving **good agreement** with the MiniBooNE data
- From then on, the npnh contribution became a key ingredient, and other theoretical models incorporated this channel in their predictions

The Martini et al. model offers a **unified description** of CCQE (1p1h), incoherent 1 π production, coherent 1 π production and npnh channels

DETAILS of the IMPLEMENTATION into GENIE

Aim of this work is to **implement** the Martini et al. model into the GENIE event generator

- The implementation concerns the **1p1h** and **npnh** channels for both neutrinos and antineutrinos
- We followed the same approach of **SuSAv2** (PRD 101, 033003, 2020) and **CRPA** (PRD 106, 073001, 2022) implementations: start from **hadron tensor tables**

$$\frac{d^2\sigma}{d\Omega_e d\omega} = \frac{G_F^2 \cos^2\theta_C}{4\pi} \frac{1}{|k|} L_{\mu\nu} W^{\mu\nu}(\omega, \mathbf{q})$$

leptonic tensor: kinematic variables
hadronic tensor: nucleon properties, nuclear dynamics

- The hadron tensor tables are calculated for ω up to 995 MeV, q up to 2000 MeV/c
- The hadron tensor tables are implemented for **^{12}C , ^{16}O and ^{40}Ca** , we can **extrapolate to other targets** using the same functions as for SuSAv2
- We kept the **same features** of the original Martini et al. model: no difference between protons and neutrons and no nuclear removal energy
- In the **npnh channel** we summed up the NN 2p2h, $\Delta\Delta$ 2p2h, $N\Delta$ 2p2h interference, and $\Delta\Delta$ 3p3h: 3p3h is included as a 2p2h contribution
- **GitHub branch:** martini2p2h soon available in a GENIE release!

VALIDATION of the 1p1h and npnh IMPLEMENTATION

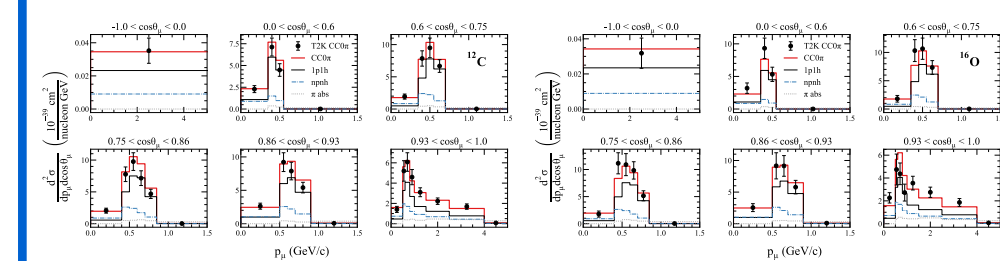
The results of the implementation of the Martini et al. for **1p1h** and **npnh** cross-sections predictions into GENIE are shown below

- Comparisons with **Nieves et al.** and **SuSAv2** models from GENIE are also shown

- **Perfect agreement** between predictions performed in GENIE and predictions performed by the authors → the **implementation is validated**
- **Channel-by-channel comparison** with other models can be **misleading**: NN correlations are included in 1p1h for SuSAv2, but in npnh for Martini et al.
- The **reexamination** by Nieves et al. (PRC 111, 025502, 2025), which is closer to Martini et al., is **not yet included** in GENIE (here).

COMPARISON with EXPERIMENTAL MEASUREMENTS

T2K CC0 π O-C JOINT ANALYSIS



Martini et al. χ^2 (reg) = 76.6 ndof = 58

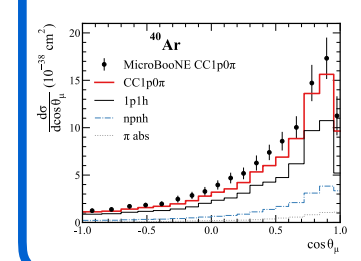
T2K analysis in PRD 101 112004 (2020)

Generator	result	Total χ^2 (shape only)	χ^2 w/o last $\cos\theta_l$ bin	ndof
NEUT 5.4.1 LFG	reg.	44.8 (38.6)	17.9 (21.1)	50
NEUT 5.4.0 SF	reg.	44.4 (32.3)	17.3 (22.5)	50
NuWro 18.2 LFG	reg.	111.0 (156.8)	43.3 (68.0)	50
NuWro 18.2 SF	reg.	64.7 (83.7)	21.0 (30.5)	50
Genie 3 LFG hA	reg.	119.2 (189.0)	48.7 (80.9)	50
Genie 3 LFG hA	reg.	66.6 (60.0)	20.1 (23.8)	50
Genie 3 LFG hA	reg.	55.4 (62.0)	22.9 (25.5)	50
Genie 3 LFG hA	reg.	52.9 (62.0)	21.3 (24.5)	50
Genie 3 SuSAv2	reg.	105.5 (105.4)	39.0 (44.7)	50
RMP (1p1h)	reg.	110.3 (111.3)	40.3 (45.6)	50
+ SuSAv2 (2p2h)	reg.	98.6 (107.5)	49.2 (68.5)	50
GIBUU	reg.	112.7 (117.0)	47.2 (58.6)	50
	reg.	107.5 (112.5)	41.7 (48.8)	50

We can **compare** the results of Martini et al. with those of other models presented in the T2K C-O CC0 π analysis:

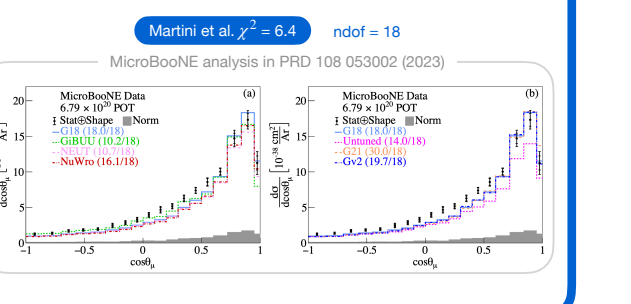
- The **largest discrepancies** among the models appear in the **last $\cos\theta_l$ bin** (last = most forward), corresponding to low energy transfer, where the **suppression** of the cross section from long-range correlations via RPA is most pronounced
- Martini et al.'s predictions perform **better** than NEUT and NuWro SF, GENIE SuSAv2, RMF+SuSAv2, and GIBUU: these models **do not include RPA effects**
- The agreement is **worse** than in GENIE, NuWro, and NEUT with LFG (Nieves et al.), with most of the discrepancy observed in ^{16}O , likely due to the absence of nuclear removal energy in the Martini et al. calculations

MicroBooNE CC1p0 π



We can **compare** the results of Martini et al. with those of other models presented in the MicroBooNE CC1p0 π analysis:

- Martini et al. provide the **best agreement** with the measurements among the considered models
- The npnh cross section predicted by our implementation is **higher** than in other models: interestingly, recent studies (e.g. PRD 111, 032009, 2025) suggest a preference for an **enhanced npnh contribution** in argon, which could explain this successful result



conferences and experiences

2nd year

done

planned

	aim	when	contribution	
JPARC - Tokai, Japan	TPC expert shifts + CM	November 2024	2 preliminary talks	
JPARC - Tokai, Japan	TPC expert shifts + CM	March 2025	1 preliminary talk	
CERN	finalising Martini's model implementation	May 2025	-	✓
IRN meeting - Lyon	conference	June 2025	talk on the HA-TPC	✓
remotely online T2K workshop	CM	July 2025	talk on the HA-TPC	✓
remotely NuFact 2025 - Liverpool	conference	September 2025	parallel talk on GENIE paper	✓
NuInt 2025 - Mainz	conference	October 2025	poster on GENIE paper	✓

conferences and experiences

3rd year

done

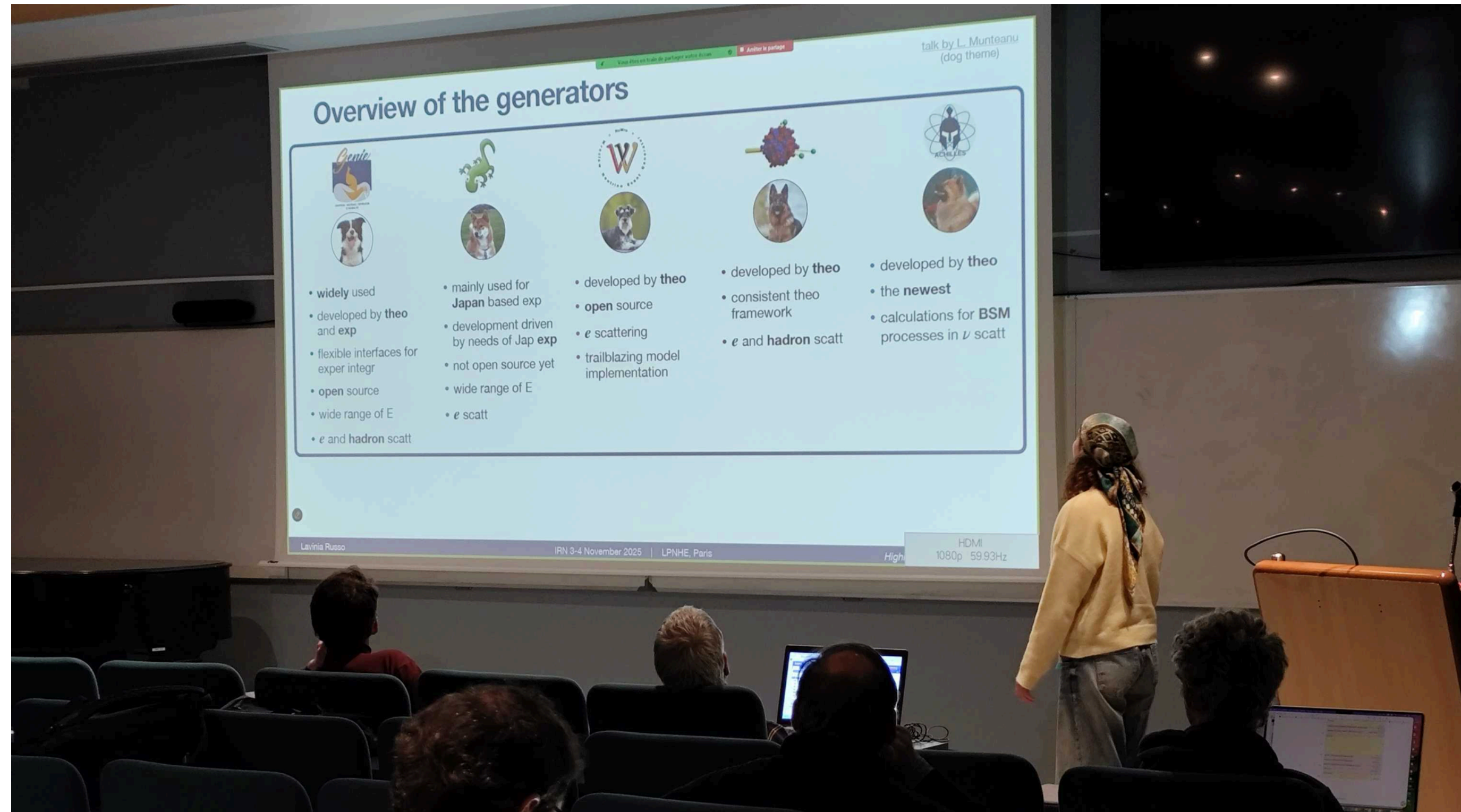
planned

	aim	when	contribution
IRN meeting - LPNHE	conference	November 2025	overview talk of NuInt
JPARC - Tokai, Japan	TPC expert shifts	January 2026	TPC expert shifts
GENIE workshop	conference	20 April 2026	talk on Martini implementation
Writing	writing	May 2026	writing
Writing	writing	June 2026	writing
Writing	writing	July 2026	writing
Writing	writing	August 2026	writing
NOW - Otranto, Italy	conference	September 2026	talk on behalf of T2K?
Soutenance de thèse	:)	27 November 2026	pot de thèse ;)

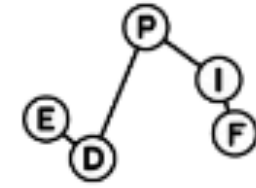
remotely

IRN Nov 2025 - Paris ✓

talk on NuInt conference



thesis writing and organisation of the defense



Sorbonne Université

Thèse de Doctorat

pour obtenir le grade de Docteur en Sciences de Sorbonne Université

Mention: Physique

L'École Doctorale Physique en Île-de-France - ED 564
Laboratoire de Physique Nucléaire et de Hautes Énergies - UMR 7585

Neutrino-Nucleus cross section studies in the T2K Near Detector ND280 and performance of the High-Angle Time Projection Chambers

présentée par
Lavinia Russo

Dirigée par
Boris Popov

Co-dirigée par
Marco Martini

Soutenue publiquement le 27 novembre 2026 devant le jury composé de :

M. Benjamin Fuks, Professeur, Sorbonne Université, HDR	Président du Jury
Mme. Christine Marquet, DR-CNRS, LP2i, HDR	Rapporteuse
M. Dominique Duchesneau, DR-CNRS, LAPP, HDR	Rapporteur
M. Andrea Longhin, Professeur, Università degli Studi di Padova	Examinateur
Mme. Alessandra Tonazzo, Professeure, UPC, HDR	Examinatrice
M. Boris Popov, DR-CNRS, LPNHE, HDR	Directeur de thèse
M. Marco Martini, Professeur IPSA, LPNHE, HDR	Co-directeur de thèse

- **jury** de thèse **approved** by the **ED**

- 6 members + 1 invité (Marco)

- **date** of the **defense set**: 27 November 2026 :)

- **writing**: we agreed on 7 chapters

- 1st chapter (overview of neutrino physics) written and revised

- I have drafts for 4 additional chapters



thesis writing and organisation of the defense

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written and revised

draft

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conclusions

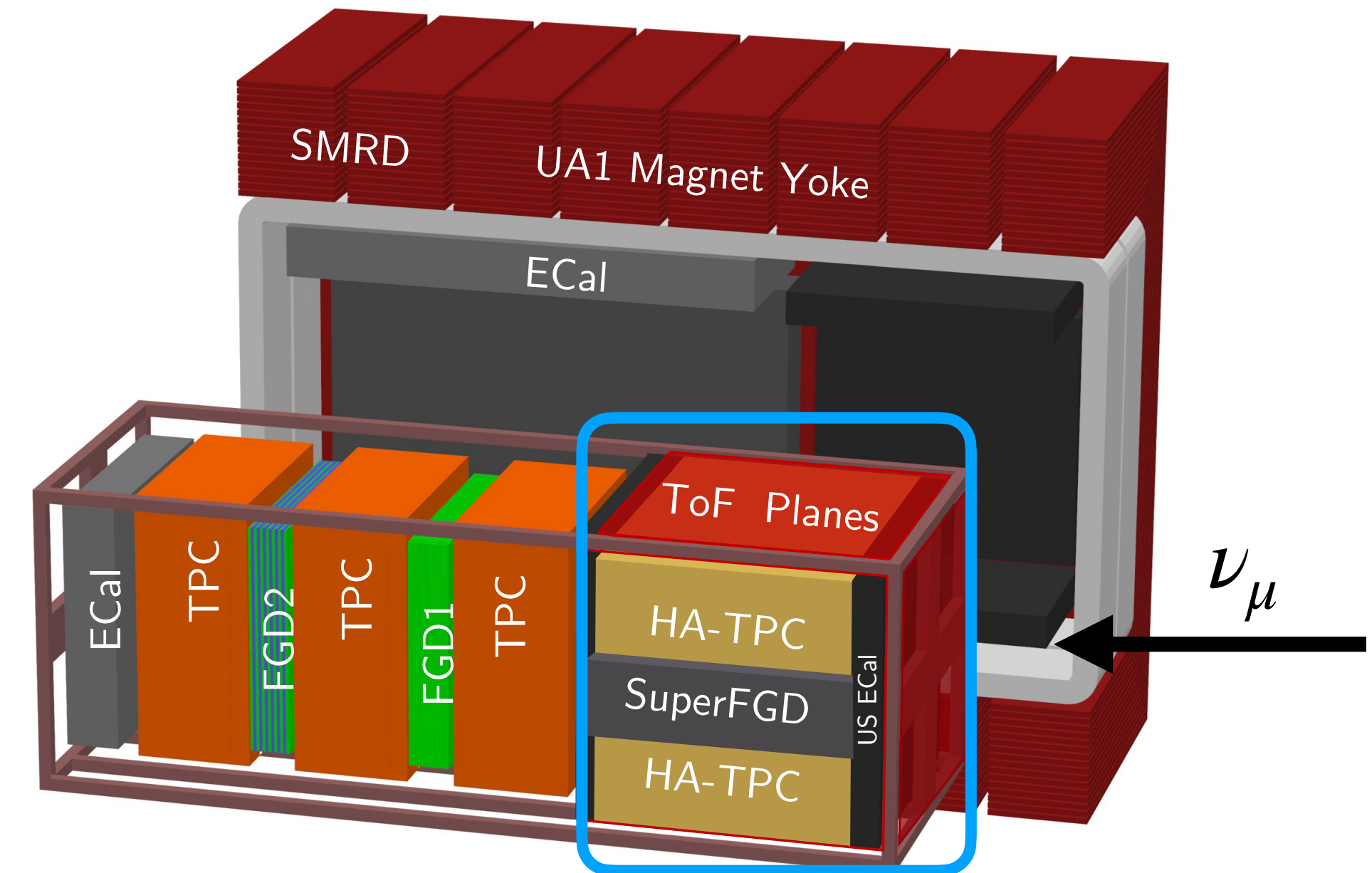
- **published 2 papers:**
 - *Implementation of the Martini-Ericson-Chanfray-Marteau RPA-based neutrino and antineutrino cross-section model in the GENIE neutrino event generator* — PRD, first author
 - *Performance of the High-Angle Time Projection Chambers in the upgraded T2K off-axis near detector* — NIMA, coauthor
- CC0 π 1p cross section analysis in the TPC gas: only **on-going project**
- thanks to my shifts in Japan I still have the rights to be **T2K author**
- **all points of ED collected**, all mandatory courses done :)
- **jury** approved by the ED, **defense date set**
- plan to **write** 7 chapters:
 - 1st one already written and revised
 - I have drafts for 4 additional chapters

Backup slides

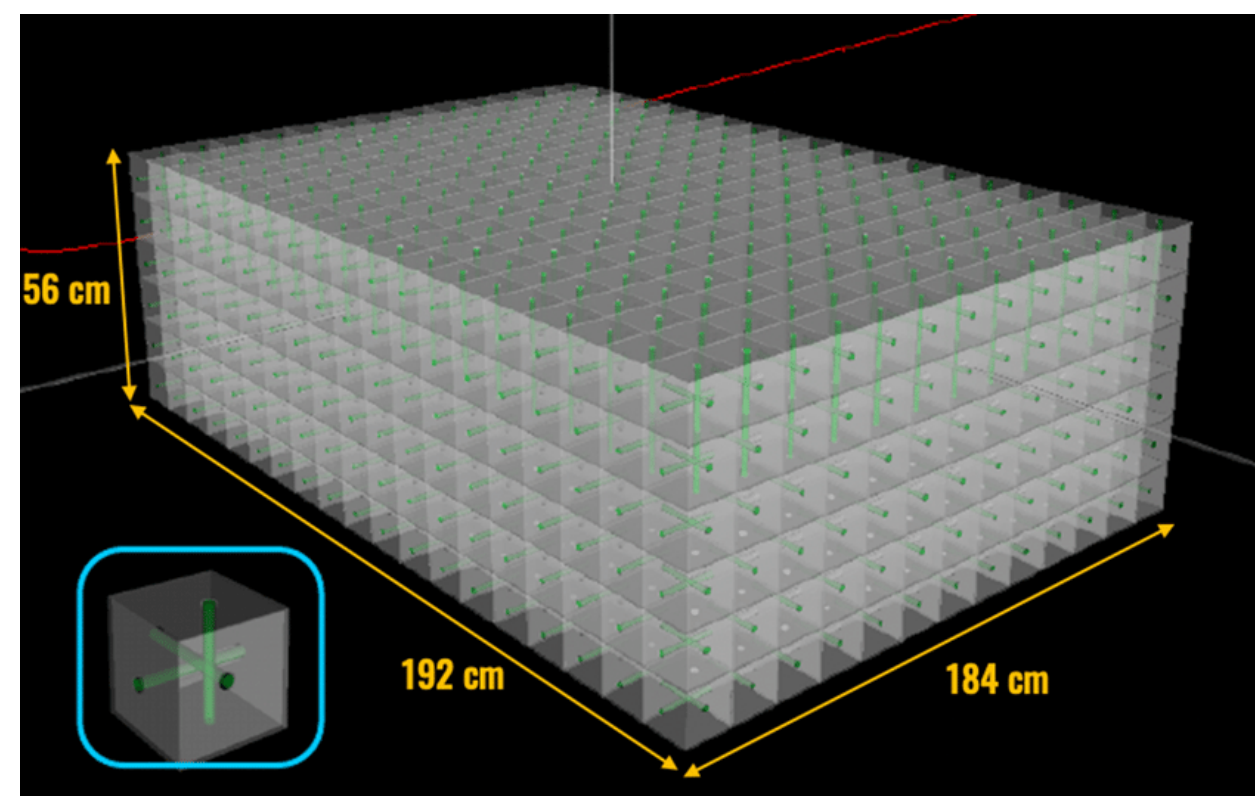
the ND280 upgrade

the motivations

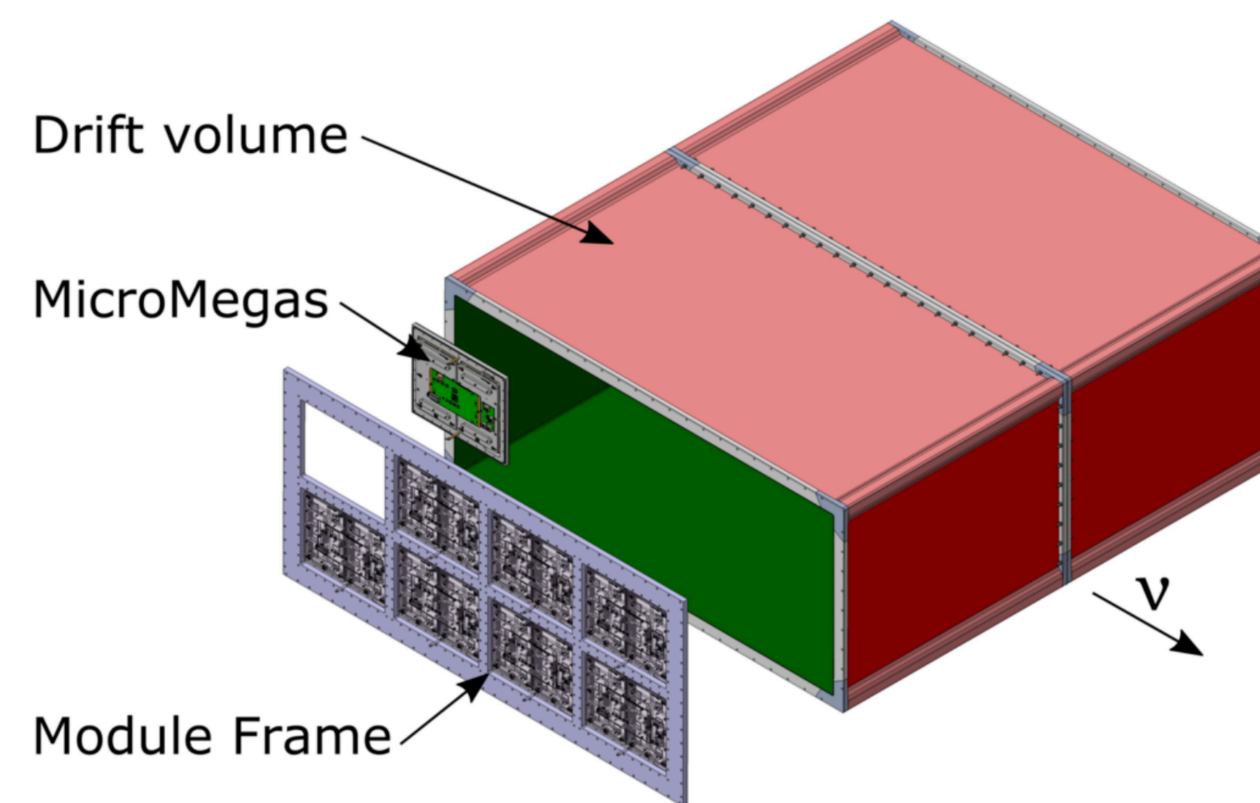
- **reduce** the ~ 400 MeV/c **reconstruction momentum threshold** and **increase** the interaction **probability**
- **reproduce** the 4π **angular acceptance** of the far detector



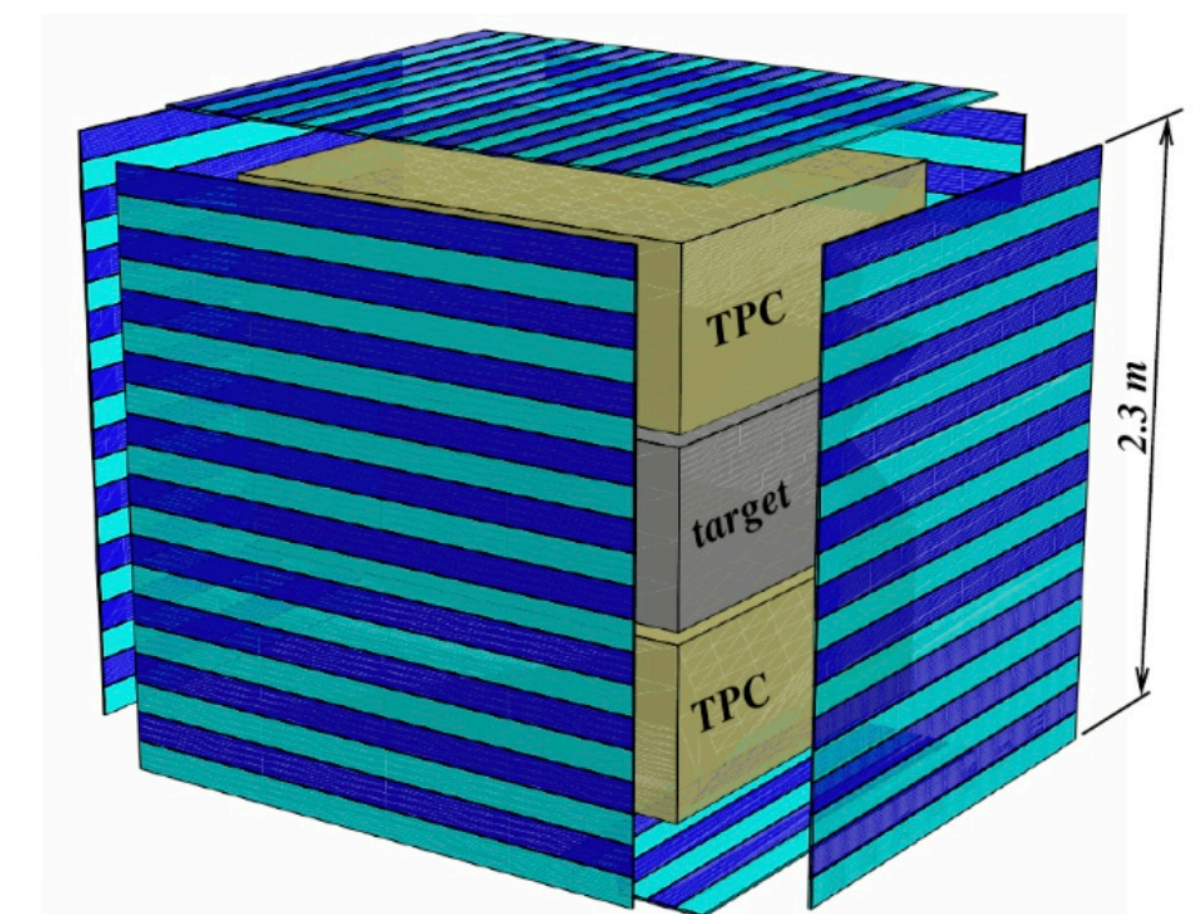
SuperFGD



2 HA-TPCs



6 TOF panles

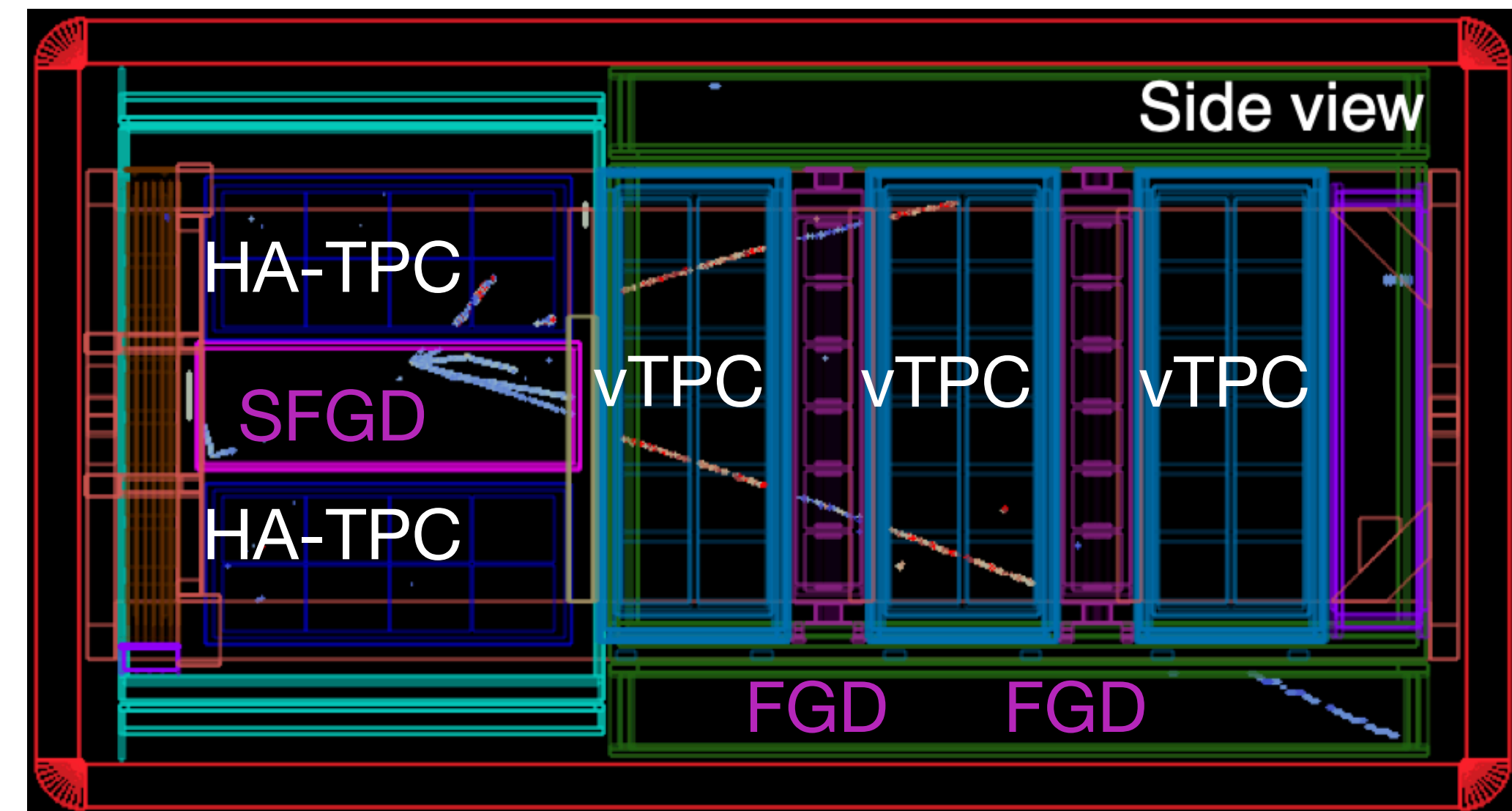
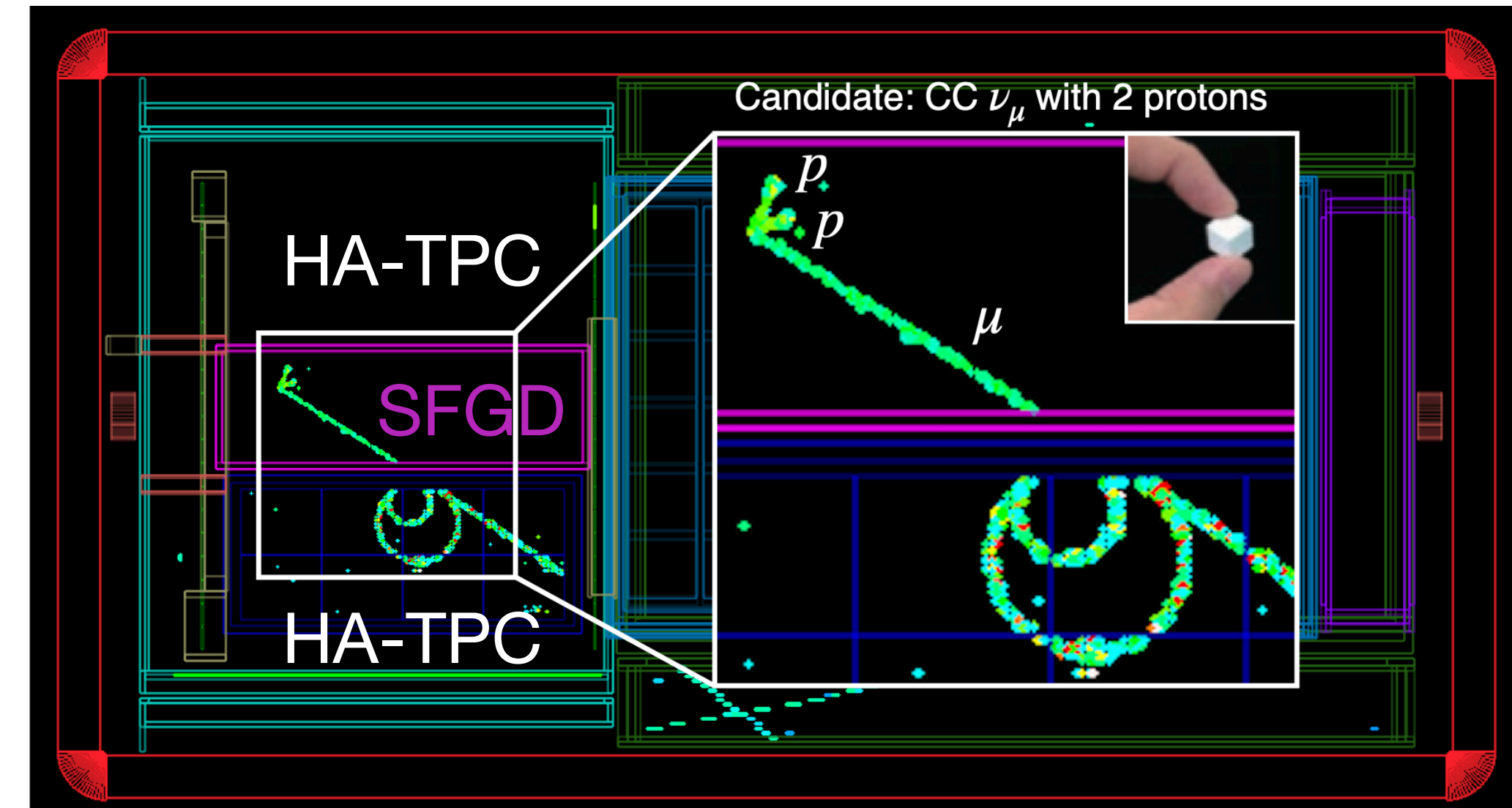


the ND280 upgrade

2 nice event displays

ND280 upgrade is **installed** and **fully operational** since **November 2024**

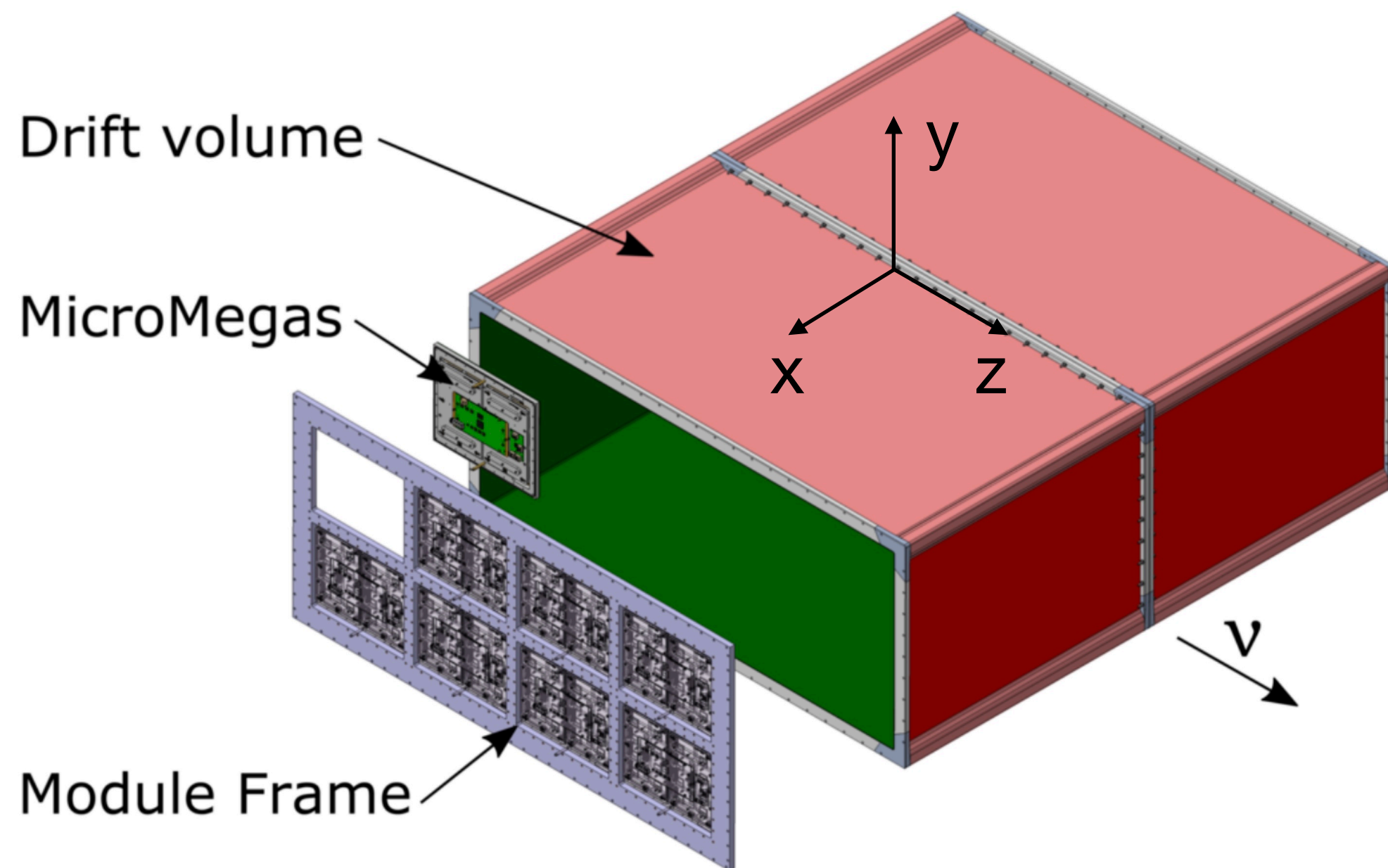
- ν interactions in the **new target SFGD**
- SFGD high granularity allows to see **proton (short) tracks**
- in $\bar{\nu}$ mode it is possible to **measure neutrons kinematics** by time of flight
- **full angle coverage** thanks to top and bottom HA-TPC
- forward going tracks are **matched** with the **downstream tracker**



the High-Angle TPC

*EP = End Plate

*ERAM = Encapsulated Resistive Anode Micromegas



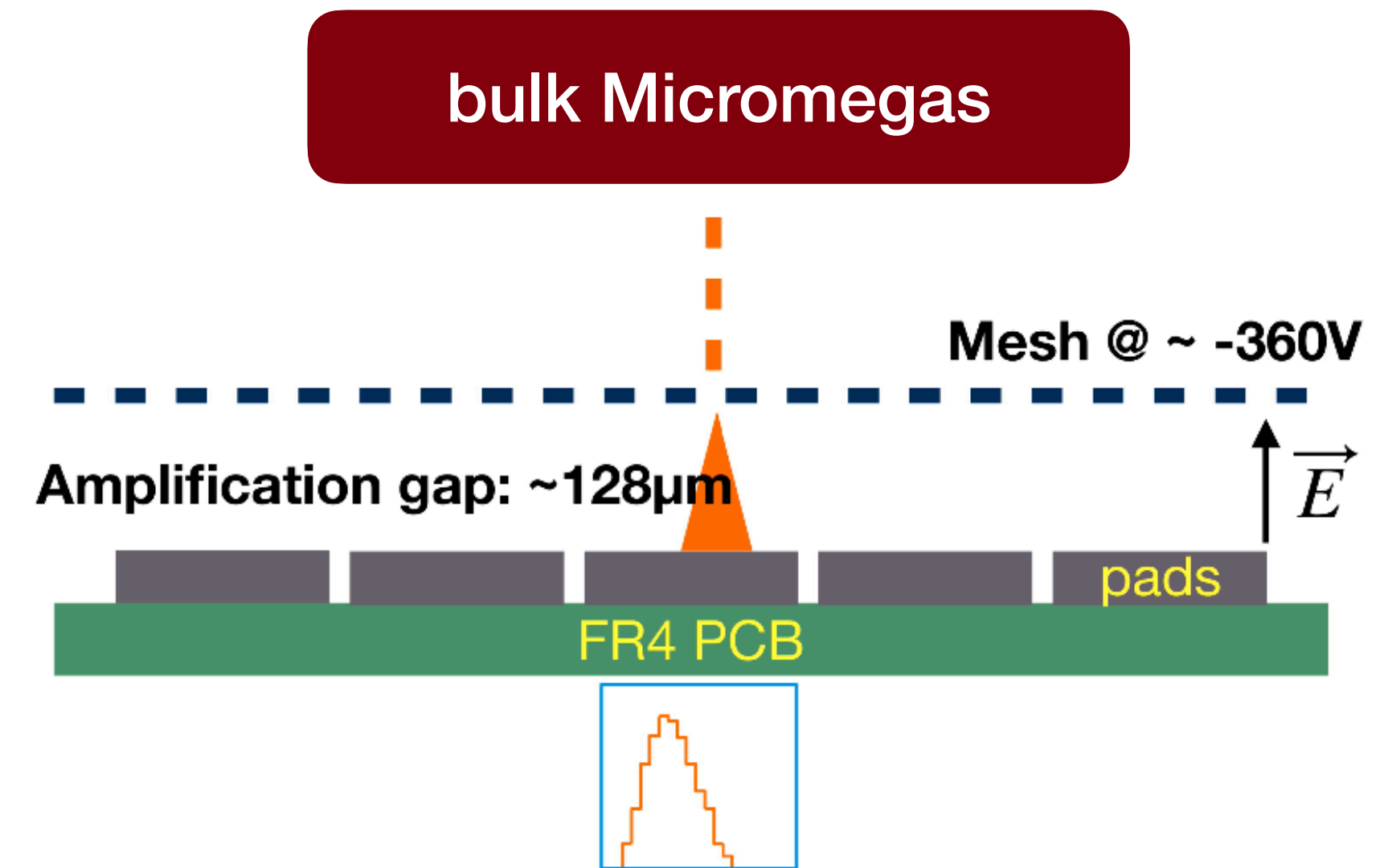
- box-like shape **gaseous detector** (Ar:CF₄:iC₄H₁₀ = 95:3:2)
- (uniform) \vec{E} in **X-direction**, (uniform) \vec{B} in **X-direction**: charged particles curve in the (Z,Y) plane
- **cathode** in the **middle**: **2 EPs*** for each HAT where the drifted electrons arrive
- **8 ERAMs*** for each **EP**: new read-out system, upgrade of the bulk Micromegas
- **1152 pads** for each ERAM organised in a 32 x 36 matrix

the Resistive Anode Micromegas of the HA-TPCs

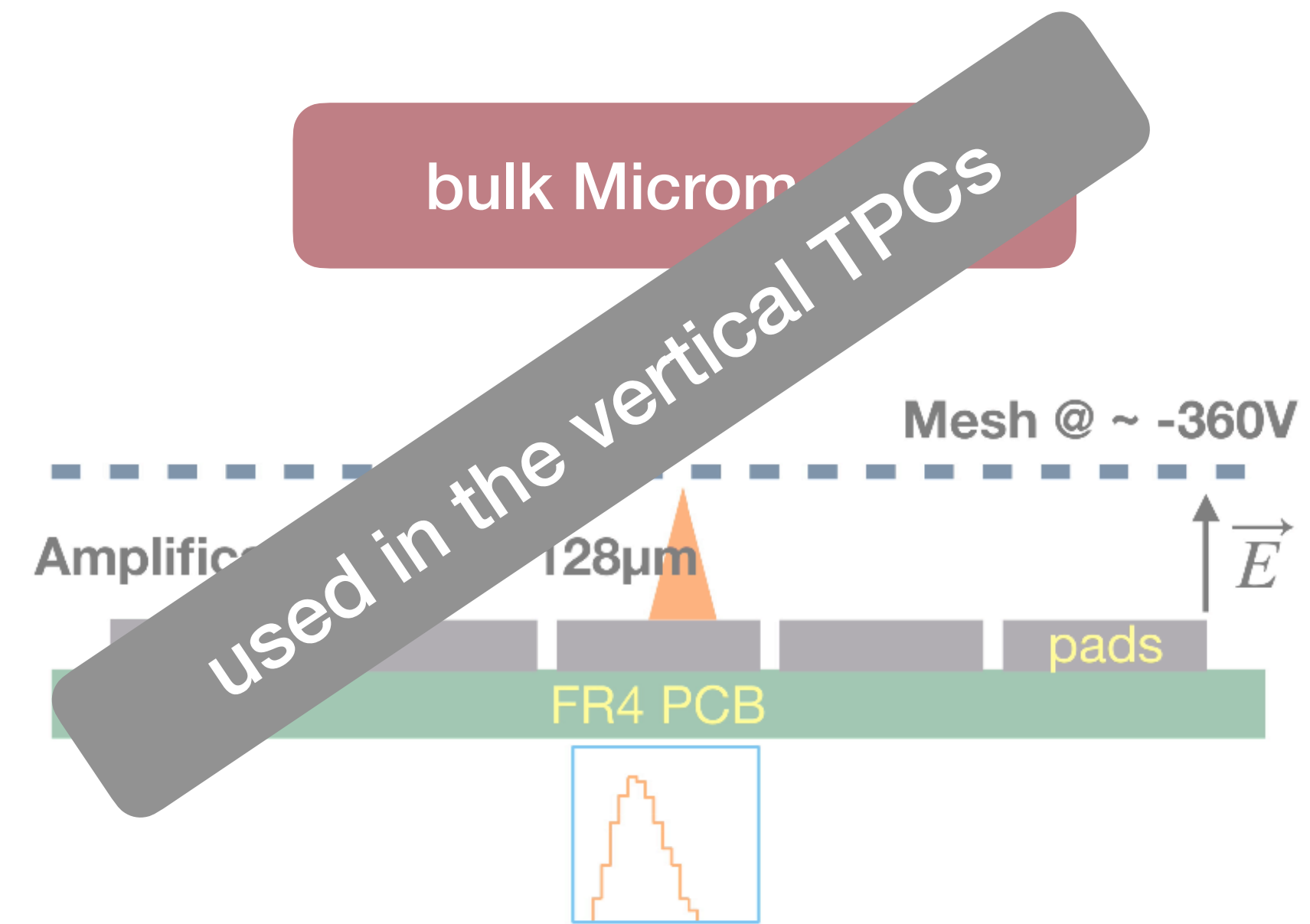
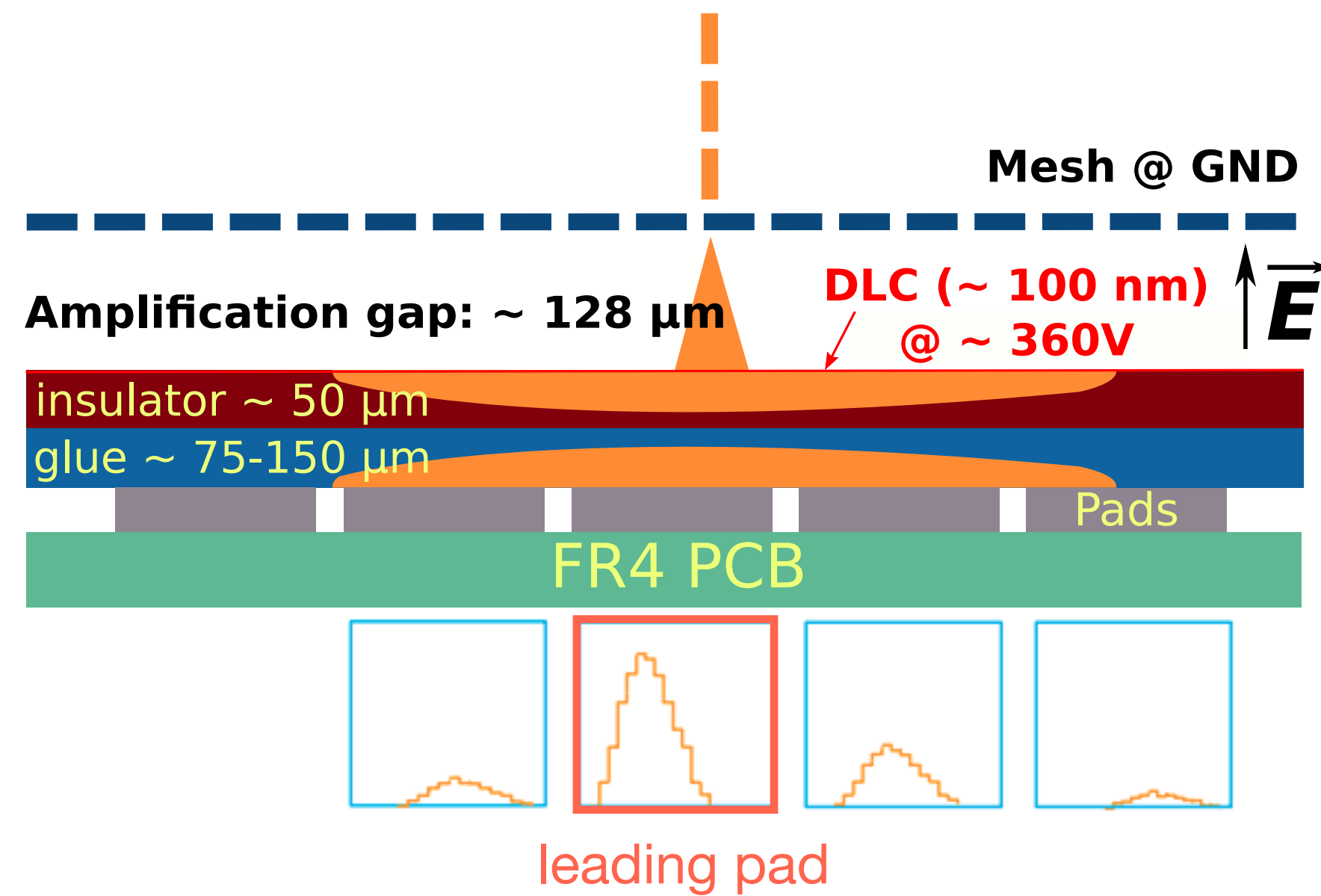
the bulk Micromegas upgrade

In both **bulk** and **resistive Micromegas**:

- **drifted electrons** arrive to the anode plane
- the signal goes through an **avalanche** process
- the signal arrives to the **pad** where it is read-out



the Resistive Anode Micromegas of the HA-TPCs



- **signal** on the anode plane is **spread over multiple pads**
- the combination of information from the **leading pad** and its **neighbours** allows for a **more precise reconstruction** of the **initial particle**
- **spatial resolution is improved** compared to bulk Micromegas