Comité de Suivi Individuel
troisième année

Lavinia Russo
Neutrino group LPNHE

17/04/2026

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

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. Dolan,[3] L. Munteanu,[3] B. Popov,[1] and C. Giganti[1]
[1]*Sorbonne Université, CNRS/IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE), Paris, France*
[2]*IPSA-DRII, 63 boulevard de Brandebourg, 94200 Ivry-sur-Seine, France*
[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 PRD

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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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Nuclear Inst. and Methods in Physics Research, A

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[a], 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. Roth[i], L. Russo[b], S. Russo[b], A. Rychter[e], W. Saenz Arevalo[b], L. Scomparin[c], Ph. Schune[a], D. Smyczek[i], R. Spina[f], J. Steinmann[i], S. Suvorov[b], N. Thamm[i], 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

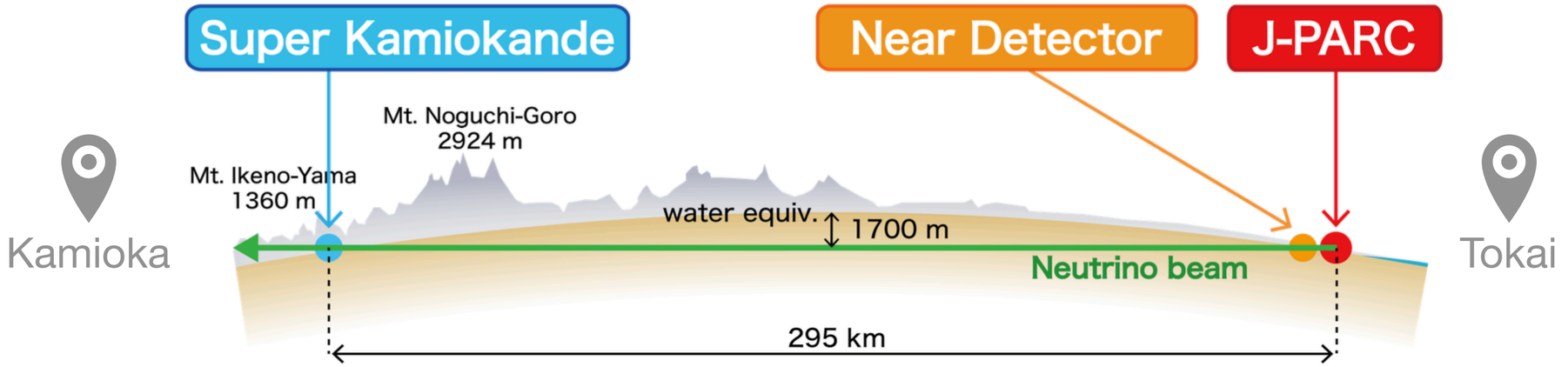
- CC0π cross section analysis:
  - looking at the interactions in the gas of the HA-TPC and vertical TPCs
  - project already started by Lukas Koch (still in T2K in Mainz)
- experiences and ED points:
  - 10 h formations d'ouverture
  - attend the 2 mandatory MOOCs
- starting writing the thesis (from the 2 on going papers)

CC0π1p interactions in the gas of the TPCs

the T2K Experiment

a long-baseline oscillation neutrino experiment

*with the help of NA61/SHINE experiment @ CERN



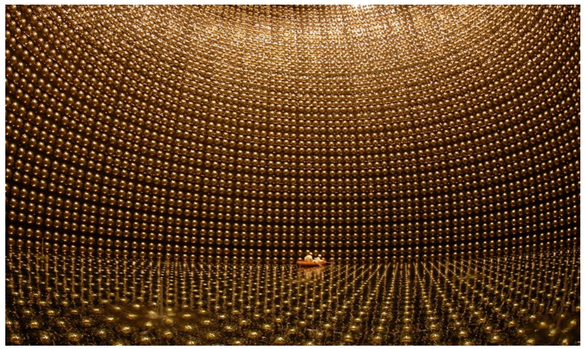
measure the ϕ_ν after the oscillation

295 km

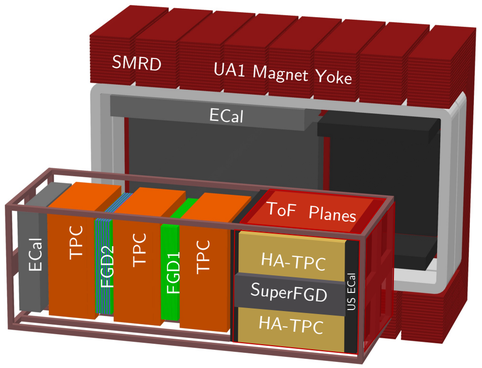
characterise the ϕ_ν before the oscillation *

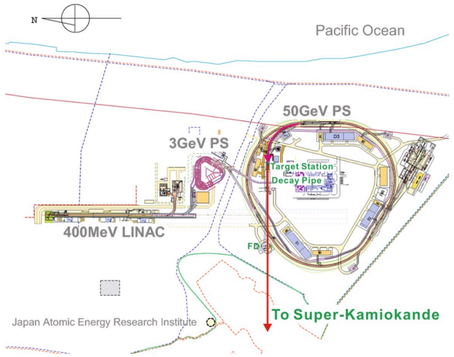
ν_μ beam production

target = ^{16}O

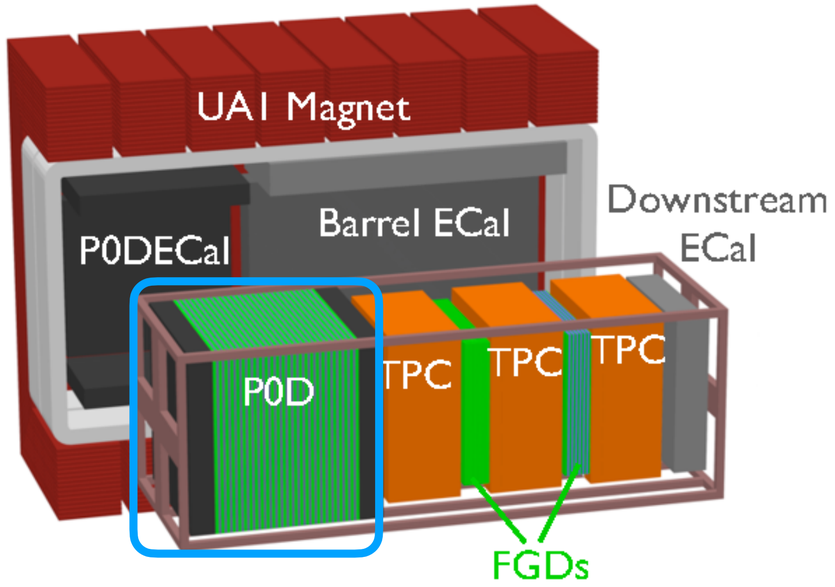


target = ^{12}C

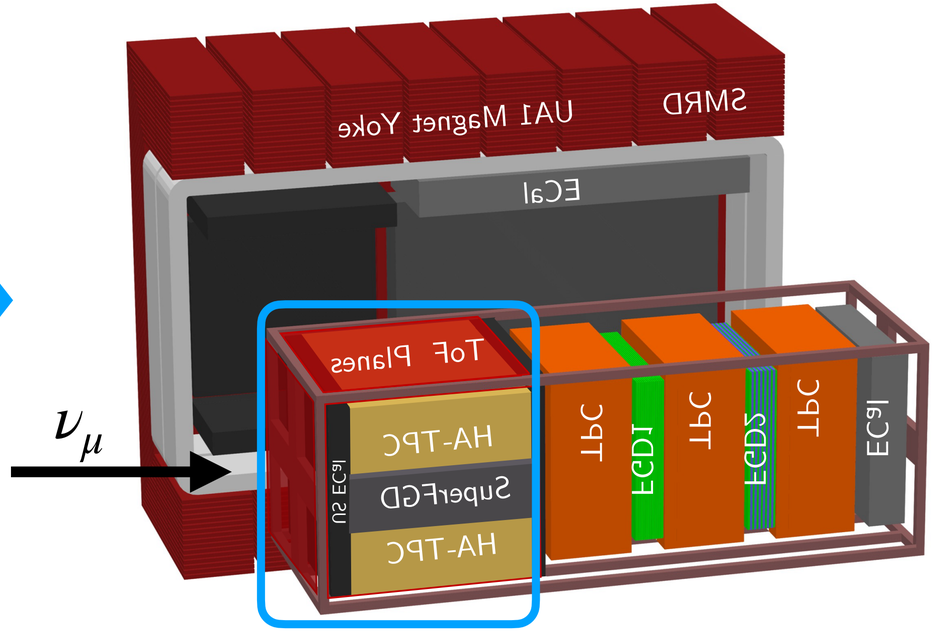




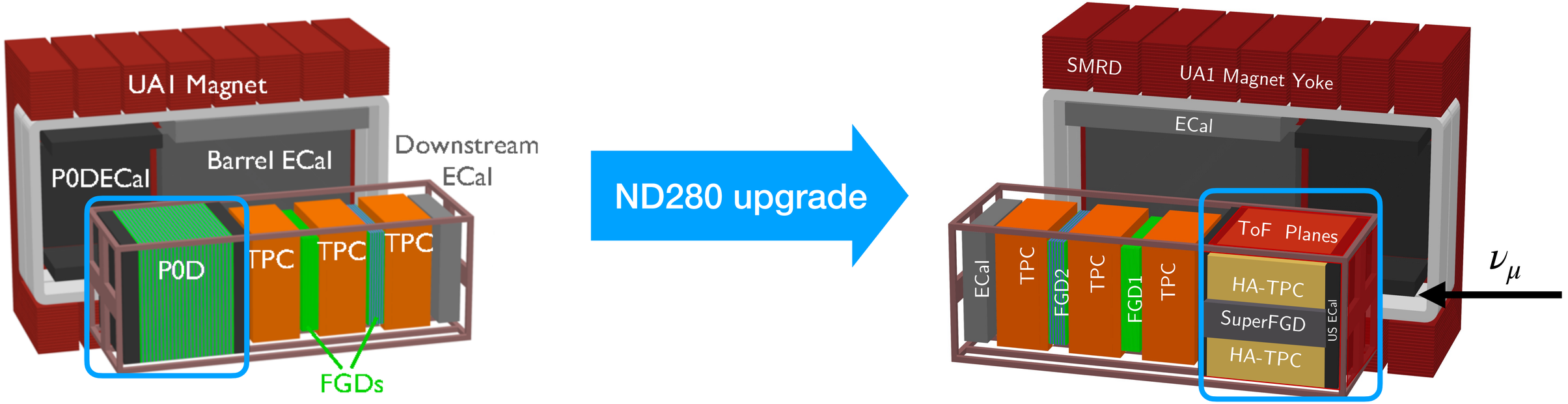
the ND280 upgrade



ND280 upgrade

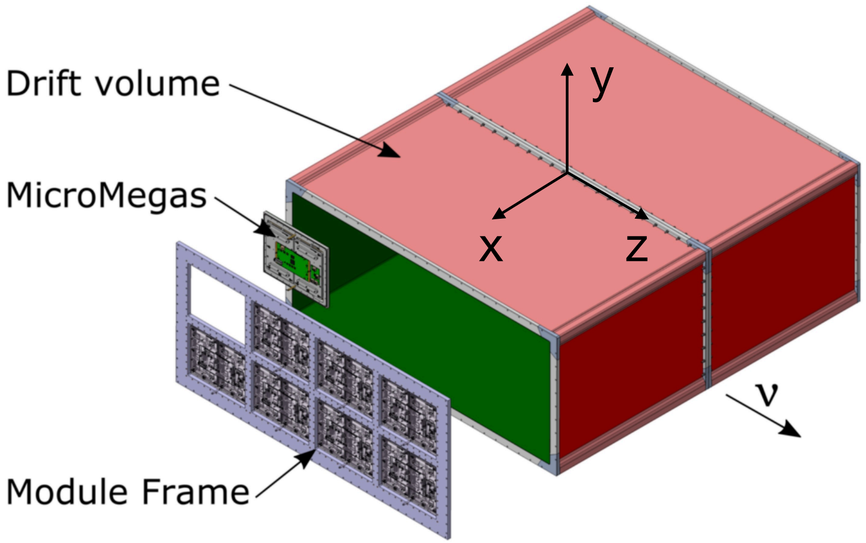


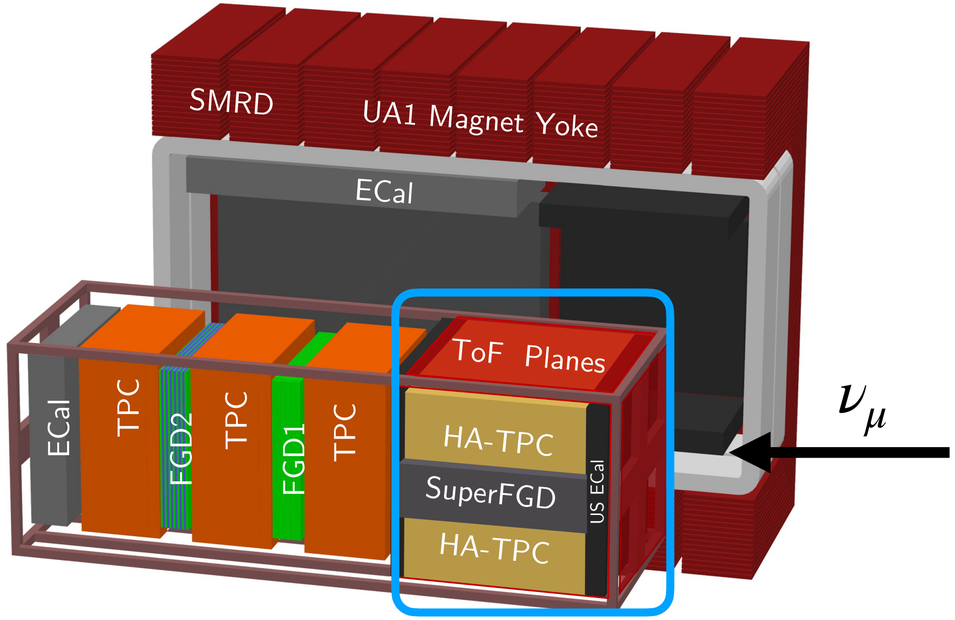
the ND280 upgrade

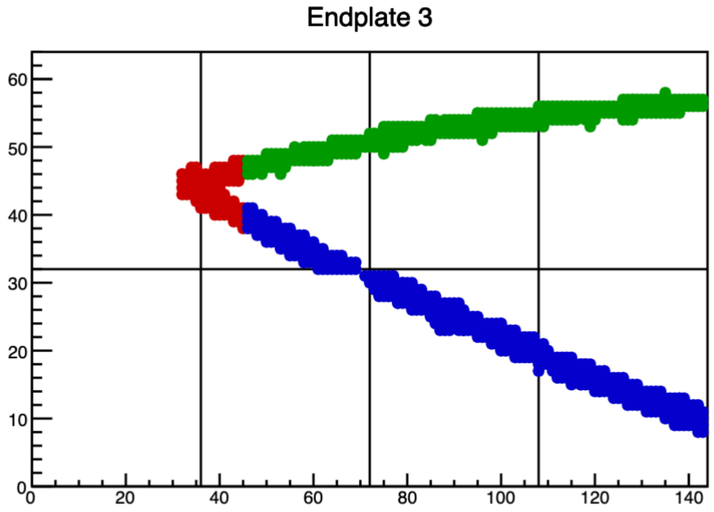


- **reduce** the ~400 MeV/c **reconstruction momentum threshold** and **increase** the interaction **probability**
- **reproduce** the 4π **angular acceptance** of the far detector

the HA-TPCs of the ND280 upgrade



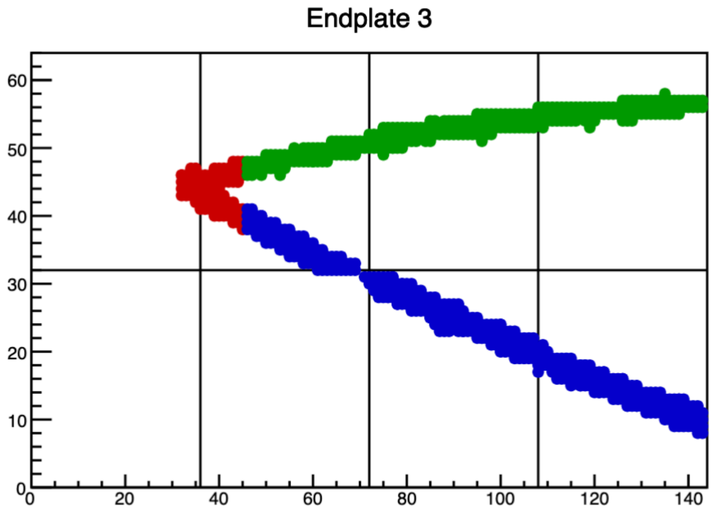


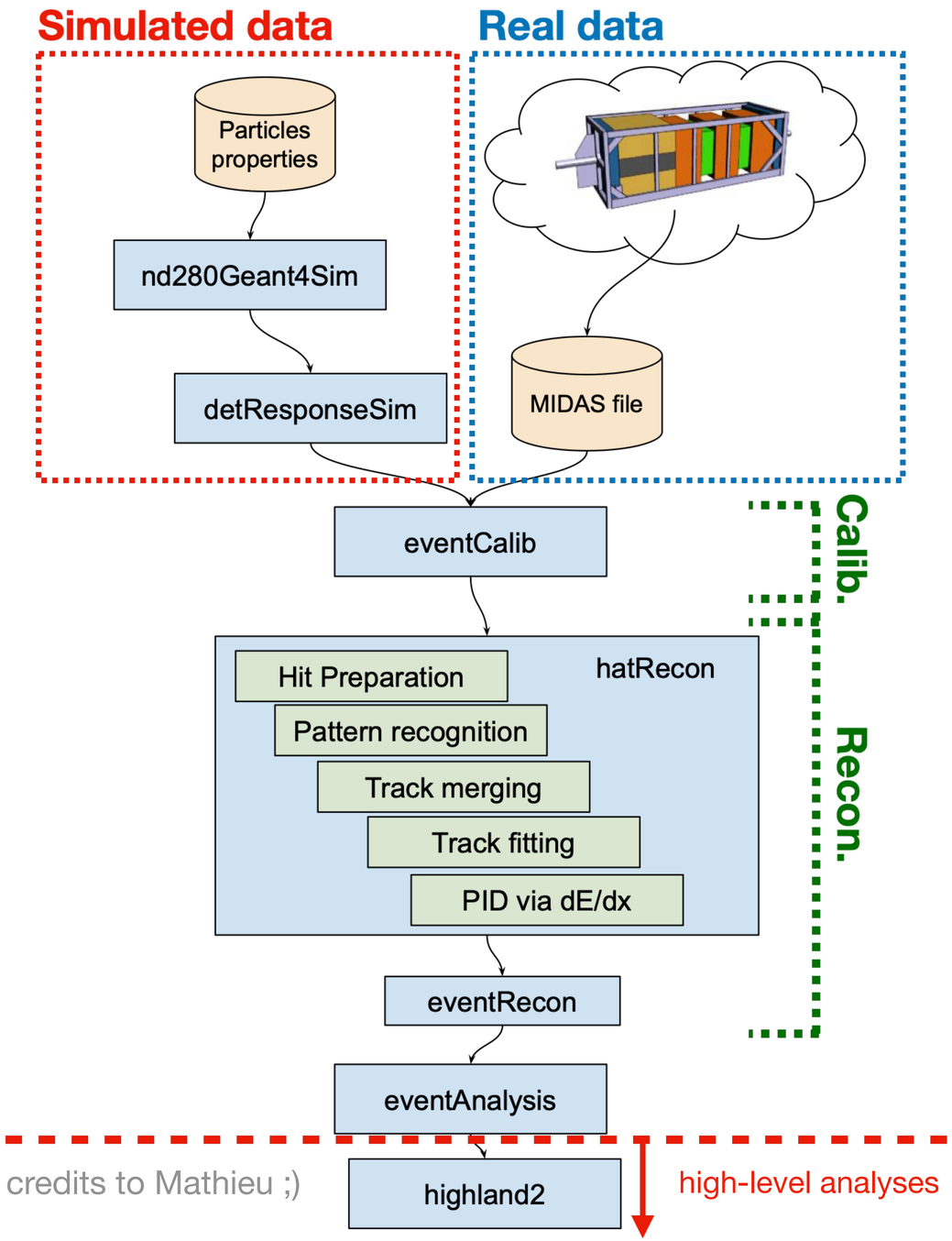


- 2 HATs with 2 endplate each
- each endplate has 8 MicroMegas modules (in a 4x2 structure)
- on the endplate plane we have a 2D reconstruction, the 3rd coordinate comes from the drift time

introduction to the project

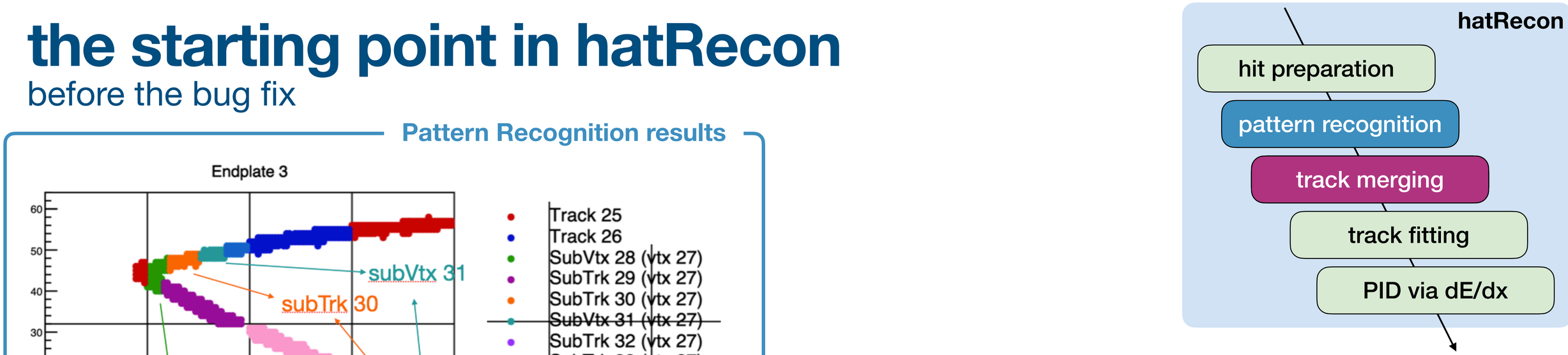
- analysis of neutrinos interactions in the gas of the HATs (vTPCs) supervised by Claudio
- CC0π1p channel: 1 proton and 1 muon in the final state
- did a Monte Carlo simulation with 1 proton and 1 muon starting from the **same vertex** in the **top HAT**





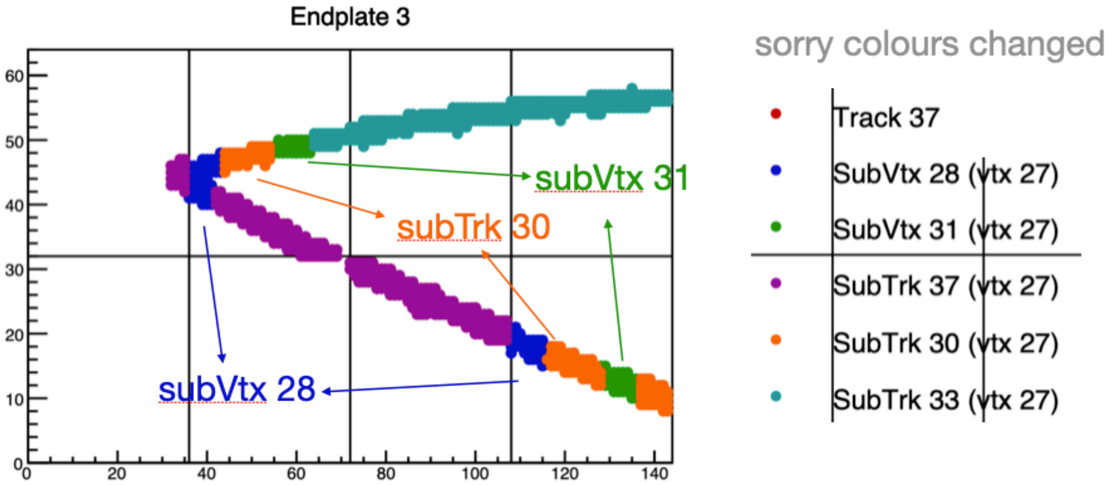
the starting point in hatRecon

before the bug fix



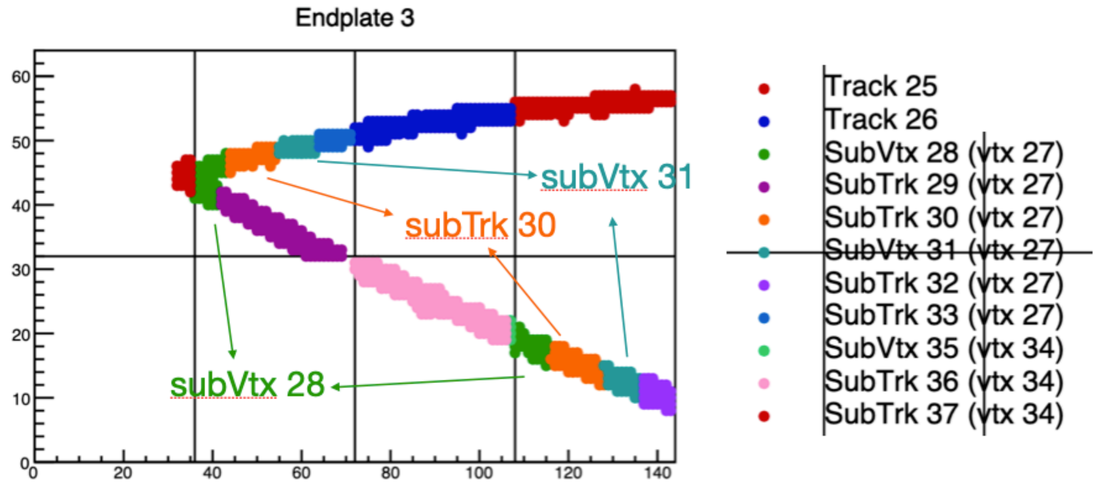
Pattern Recognition results

Merge Fit results

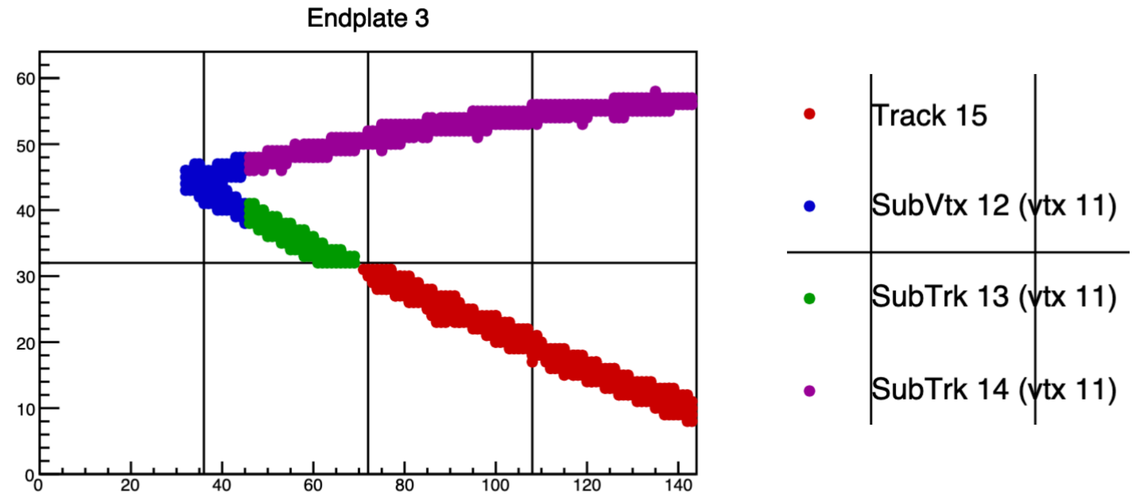


before the bug fix … and … after the bug fix

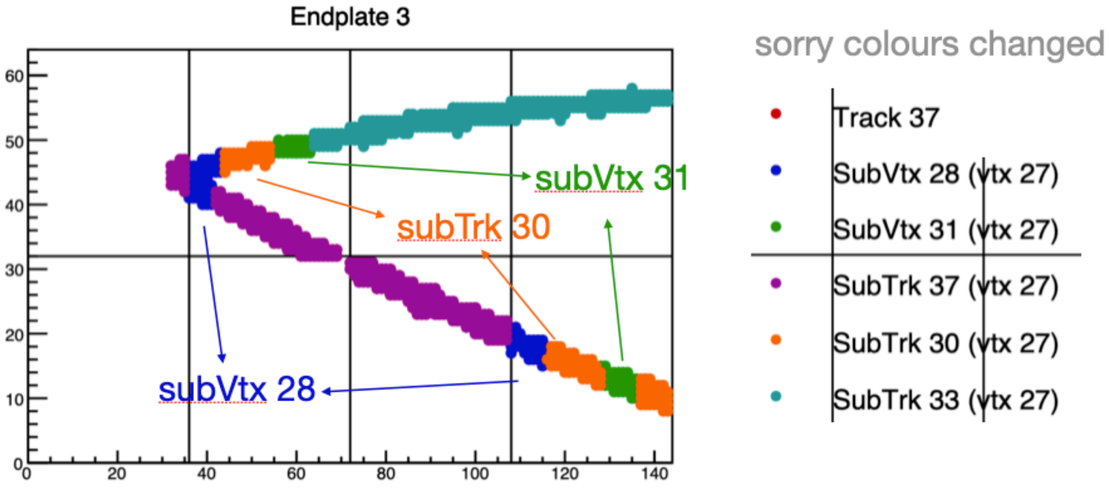
Pattern Recognition results



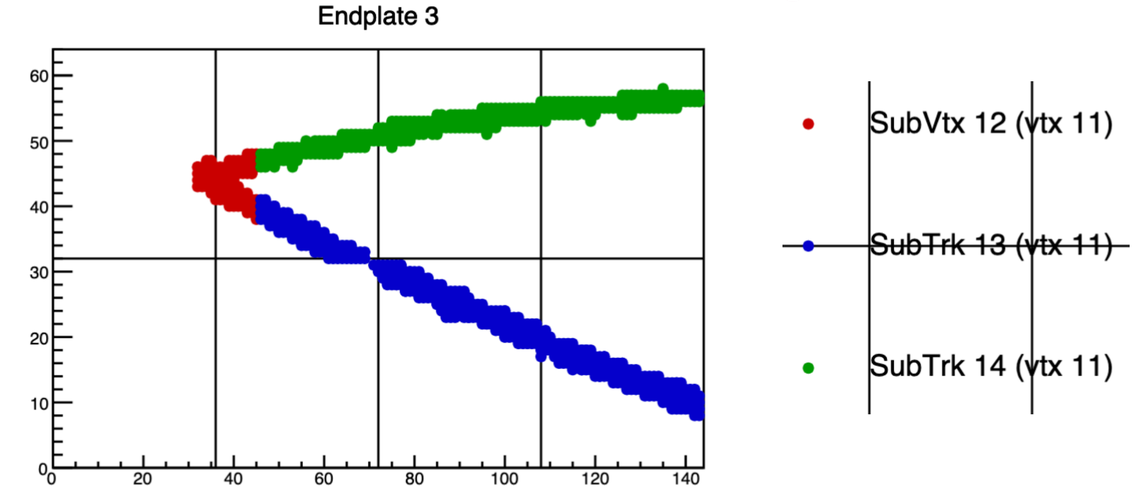
Pattern Recognition results



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

vertex
- subtrack 1
- subtrack 2

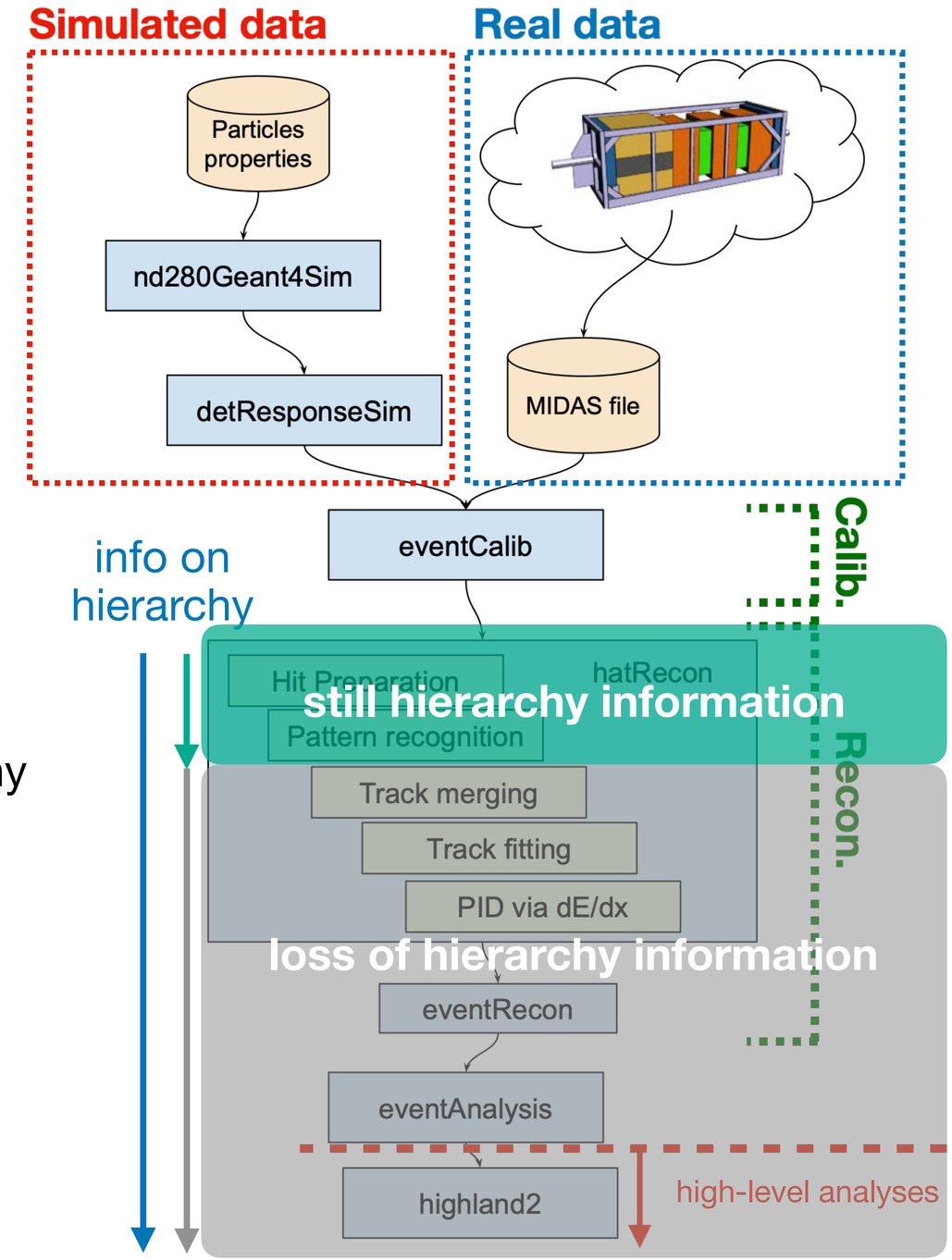
track 3

→

after pattern recognition

track 1
track 2
track 3

- 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)



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until pattern recognition

vertex
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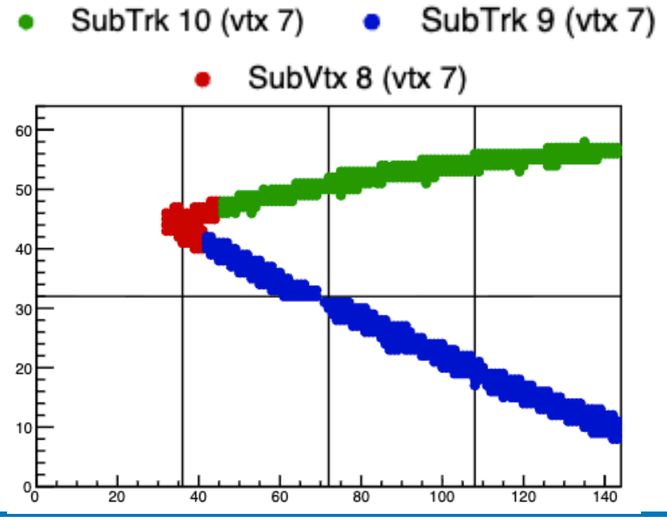
- subtrack 2

track 3

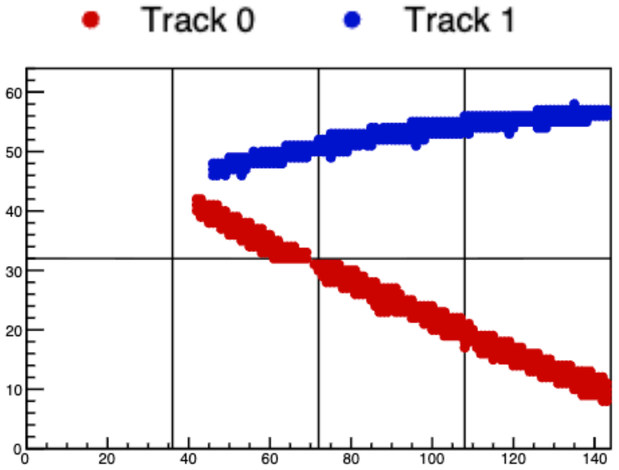
after pattern recognition

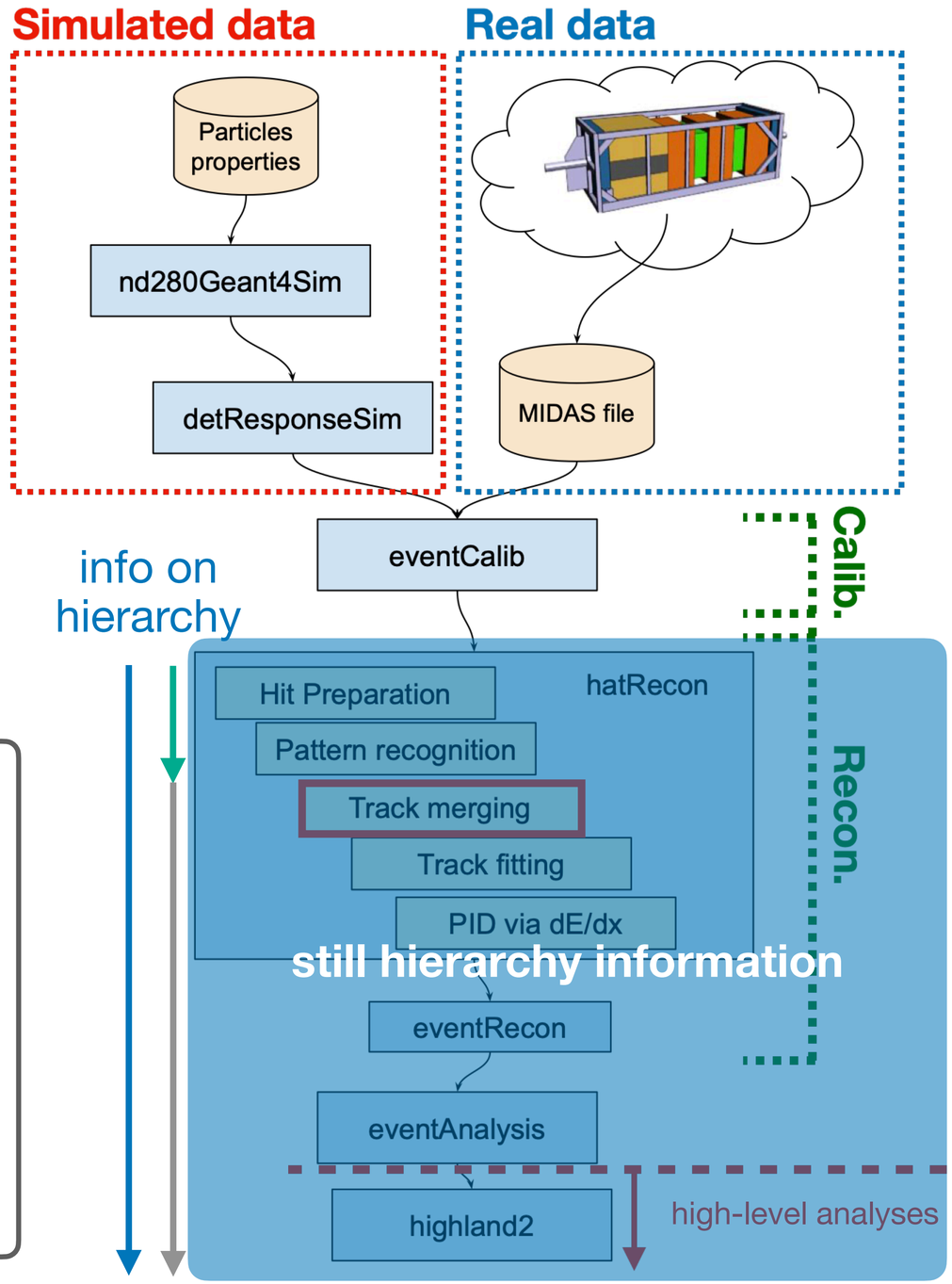
track 1
track 2
track 3

Merge Fit results (my work)



Merge Fit results (official release)

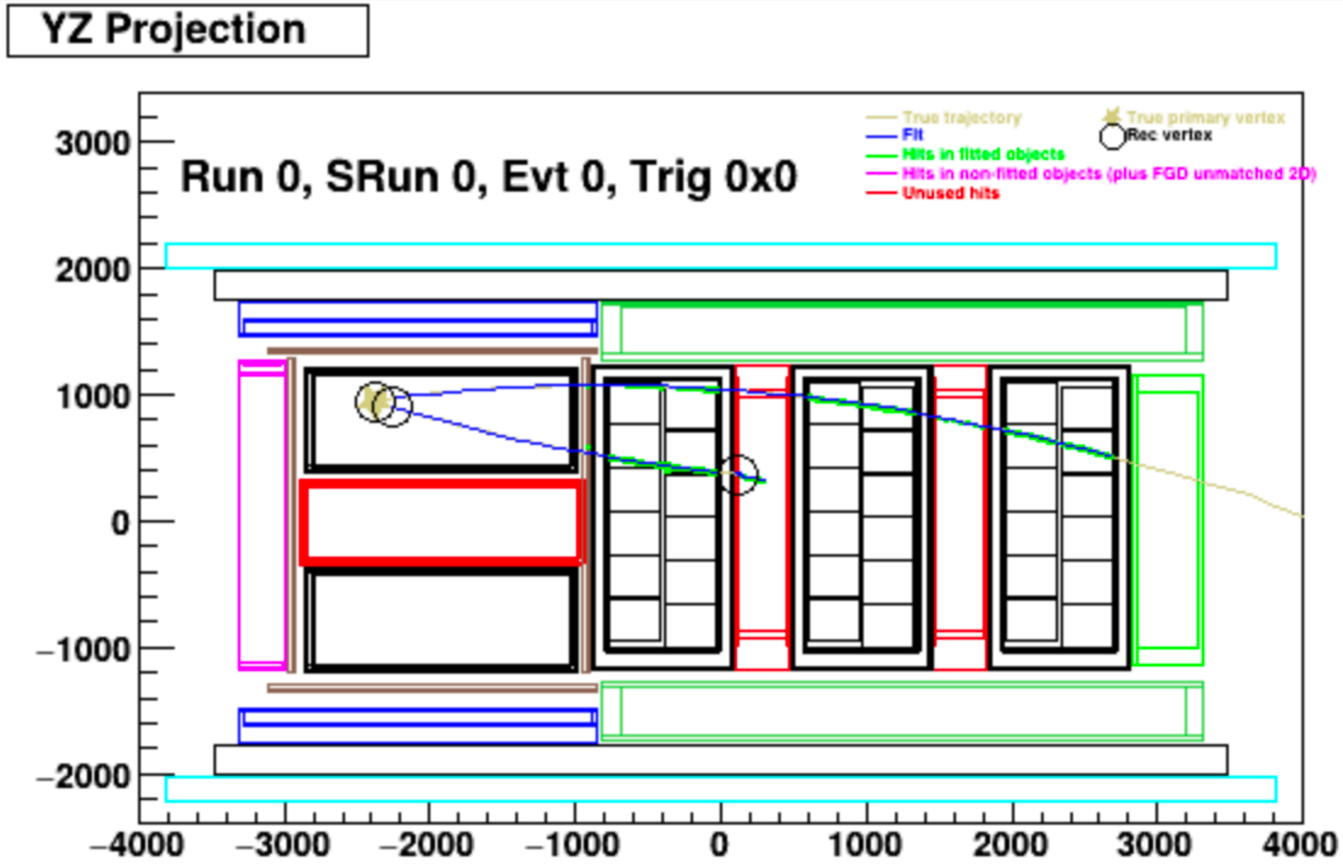


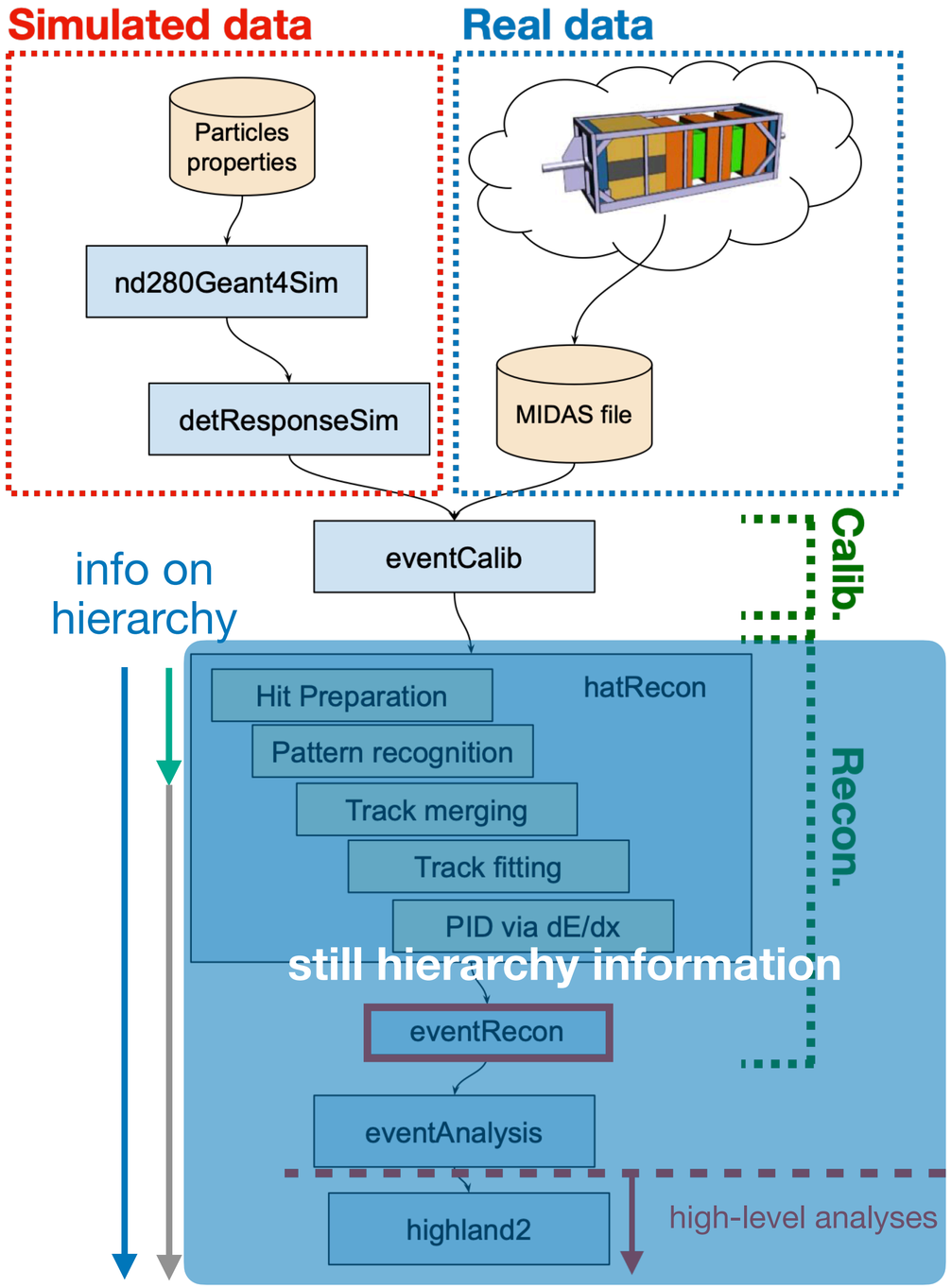


today's status

eventRecon results

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





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 cathegory
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

obligatoire

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transverses
60 h → 40 h

scientifiques
40 h

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

conferences and experiences

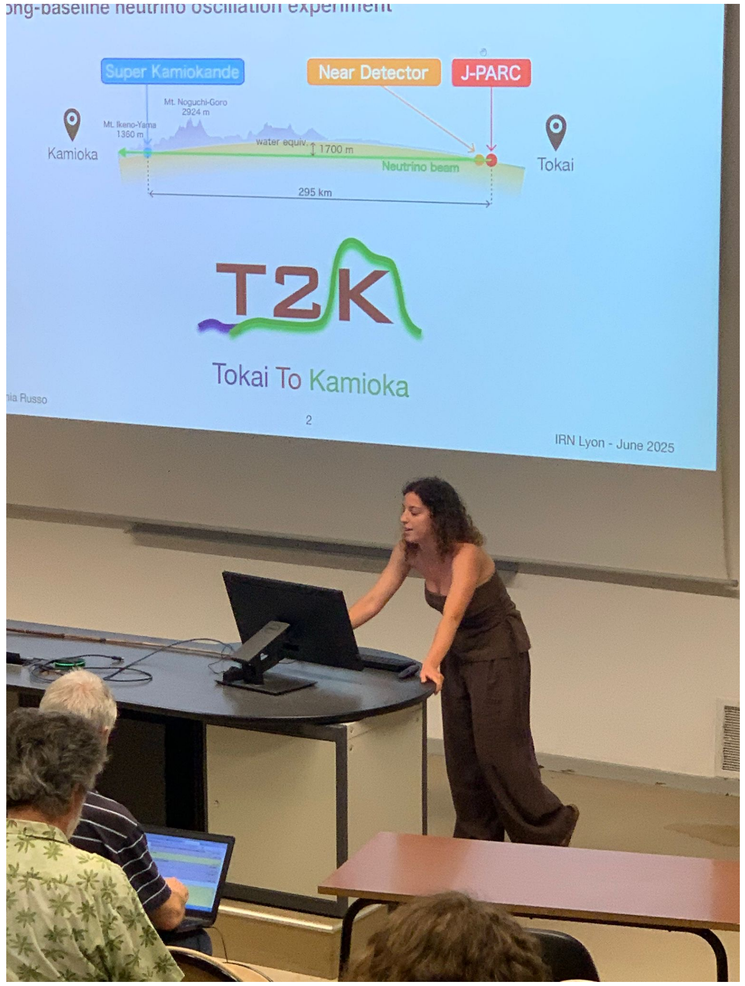
2nd year

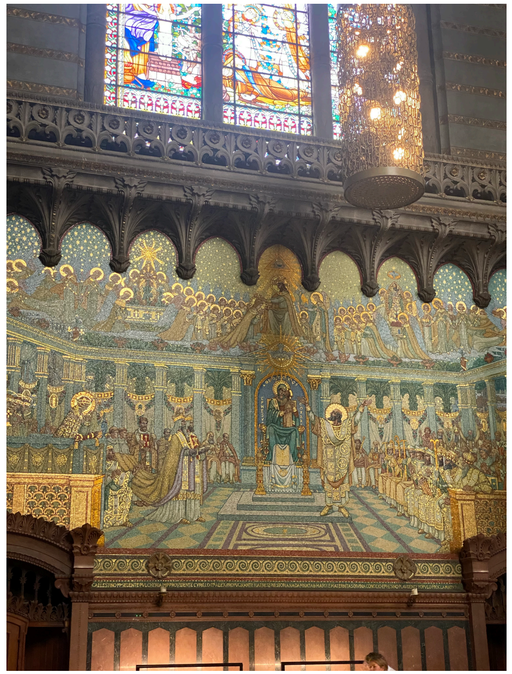
done planned

	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
NuFact 2025 - Liverpool	conference	September 2025	parallel talk on GENIE paper
NuInt 2025 - Mainz	conference	Octorber 2025	poster on GENIE paper

IRN June 2025 - Lyon ✓

talk on ND280 upgrade





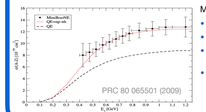
NuInt 2025 ✓

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



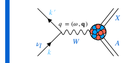
Martini, Ericson, Chanfray and Marteau provided the **explanation** for the **MiniBooNE** CCQE-like **cross section**:

- 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 1π production, coherent 1π 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**



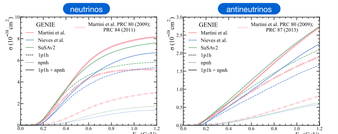
$$\frac{d^2\sigma}{d\Omega_{k'}\, d\omega} = \frac{G_F^2 \cos\theta_C}{4\pi} \frac{|\mathbf{k}'|}{|\mathbf{k}|} L_{\mu\nu} W^{\mu\nu}(\omega, \mathbf{q})$$

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, ΔΔ 2p2h, NΔ 2p2h interference, and ΔΔ 3p3h; 3p3h is included as a 2p2h contribution
- **GitHub branch:** martini2p2h soon available in a GENIE release!

VALIDATION of the 1p1h and npnh IMPLEMENTATION

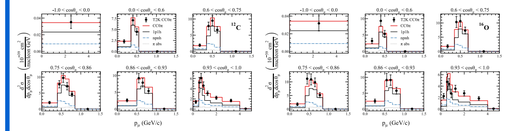
- The **results** of the implementation of the Martini et al. for **1p1h** and **npnh** cross-sections predictions into GENIE are shown below
- **Comparisons** with **Nieves et al.** and **SuSAv2** models from GENIE are also shown



- **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 CC0π O-C JOINT ANALYSIS



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

T2K analysis in PRD 101 112004 (2020)

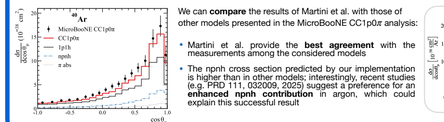
Generator	reweight	Total χ^2 (shape only) (ndof = 58)	χ^2 w/o last $\cos\theta_\mu$ bin (ndof = 50)
NEUT 5.4.1 LFG	reg.	44.4 (58.6)	17.9 (21.1)
	unreg.	44.4 (62.3)	17.3 (22.5)
NEUT 5.4.0 SF	reg.	111.0 (156.8)	65.3 (80.0)
	unreg.	116.4 (166.7)	65.1 (75.1)
NuWro 18.2 LFG	reg.	64.7 (83.7)	21.0 (30.5)
	unreg.	66.8 (98.7)	21.1 (32.1)
NuWro 18.2 SF	reg.	114.5 (180.1)	50.2 (80.9)
	unreg.	119.2 (189.0)	48.7 (80.9)
Genie 3 LFG kN	reg.	48.9 (58.5)	22.3 (24.6)
	unreg.	46.6 (80.0)	20.1 (23.8)
Genie 3 LFG hA	reg.	55.4 (92.0)	22.9 (25.5)
	unreg.	52.9 (92.0)	21.0 (24.5)
Genie 3 SuSAv2	reg.	103.5 (105.4)	39.0 (44.7)
	unreg.	110.5 (111.3)	40.3 (45.6)
RMF (1p1h) + SuSAv2 (2p2h)	reg.	90.0 (97.3)	48.2 (60.5)
	unreg.	95.8 (102.2)	49.3 (60.7)
GiBUU	reg.	112.7 (117.0)	47.2 (50.6)
	unreg.	107.5 (112.2)	41.7 (46.8)

We can **compare** the results of Martini et al. with those of other models presented in the T2K C+O CC0π analysis:

- The largest **discrepancies** among the models appear in the last cosθ 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 CC1p0π

Martini et al. χ^2 = 6.4 ndof = 18



We can **compare** the results of Martini et al. with those of other models presented in the MicroBooNE CC1p0π 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

LPNHE, Sorbonne Université, CNRS/IN2P3, Paris
lavinia.russo@in2p3.fr | poster ID #258

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 **T2K workshop - CERN**	CM	July 2025	talk	✓
remotely **NuFact 2025 - Liverpool**	conference	September 2025	parallel talk on GENIE paper	✓
NuInt 2025 - Mainz	conference	Octorber 2025	poster on GENIE paper	✓

conferences and experiences

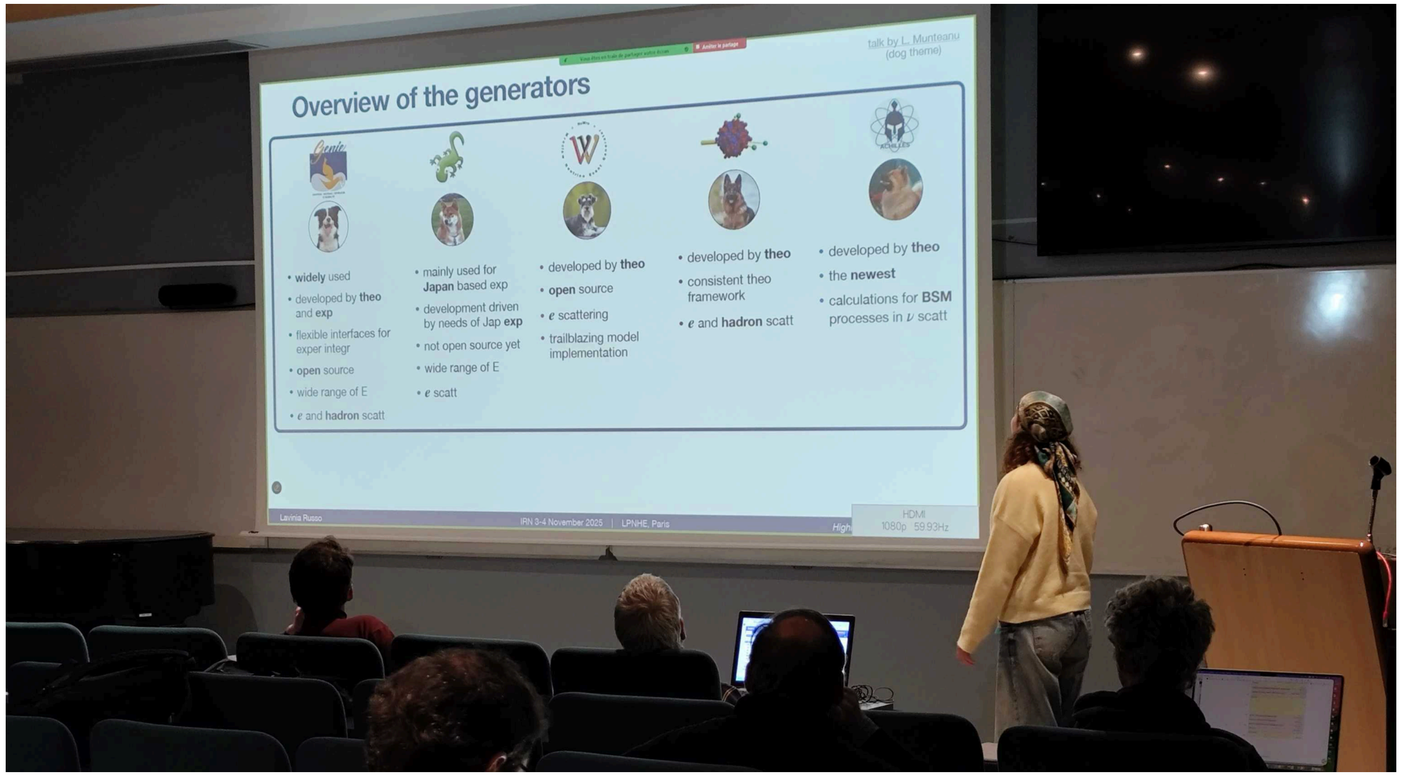
3rd year

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 remotely	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
Soutenance de thèse	:)	27 November 2026	pot de thèse ;)

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 15 novembre 2026 devant le jury composé de :

M. Benjamin Fuks, Professeur, Sorbonne Université, HDR	Président du Jury
Mme. Christine Marquet, DR-CNRS, LP2i, HDR	Rapportrice
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 fixed:** 27 November 2026 :)
- 1st chapter written, we agreed on 6 more. Working on it !

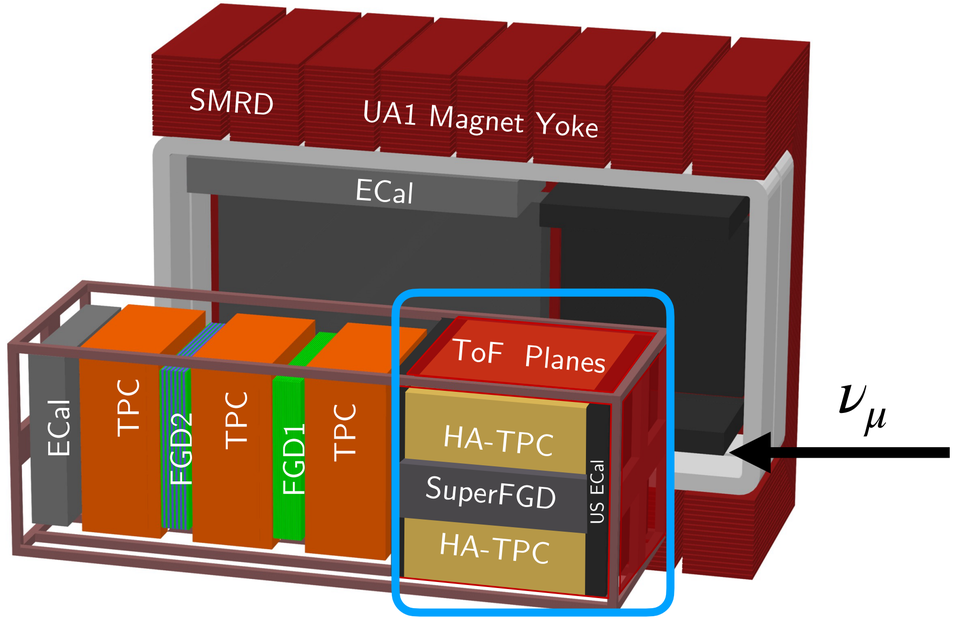
conclusions

- **published 2 papers**:
  - *Implementation of the Martini-Ericson-Chanfray-Marteau RPA-based neutrino and antineutrino cross-section model in the GENIE neutrino event generator* — PR D, first author
  - *Performance of the high-angle time projection chambers in the upgraded T2K off-axis near detector* — NIM A, coauthor
- 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, **defense date** fixed
- plan to **write** 7 chapters:
  - first one (overview of neutrino physics) already written and revised
  - I have drafts for three additional chapters

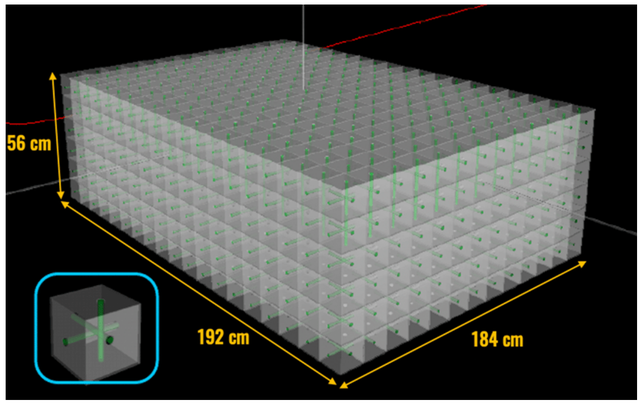
Backup slides

the ND280 upgrade
the motivations

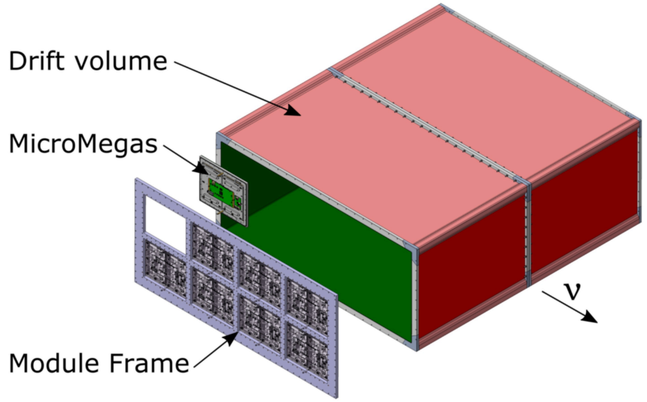
- **reduce** the ~400 MeV/c **reconstruction momentum threshold** and **increase** the interaction **probability**
- **reproduce** the 4π **angular acceptance** of the far detector



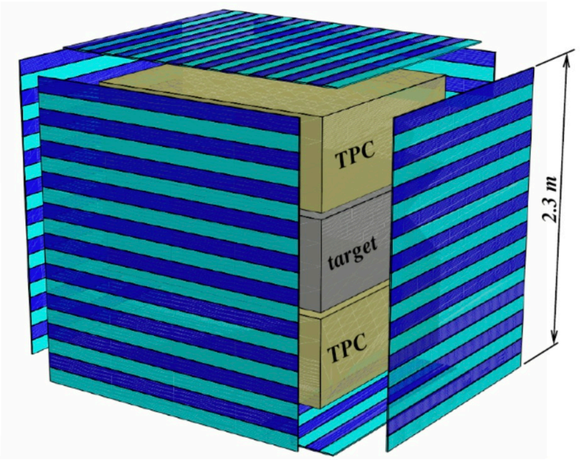
SuperFGD



2 HA-TPCs



6 TOF panles

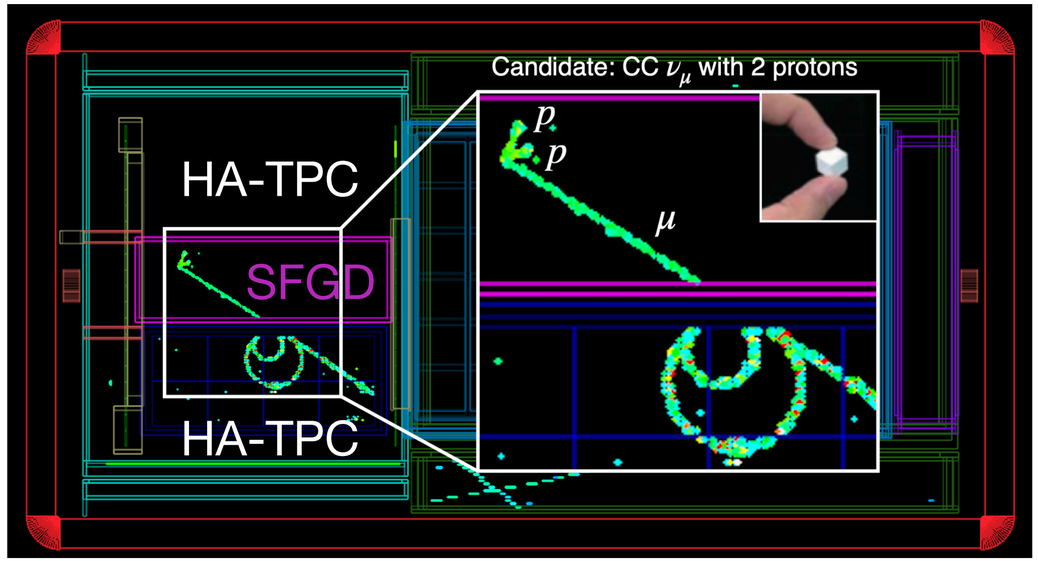


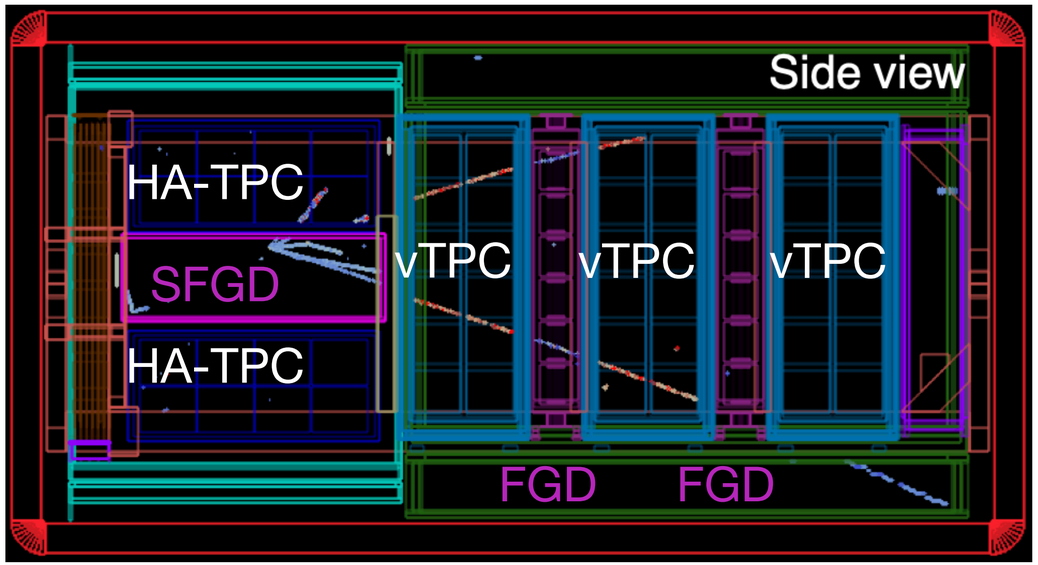
the ND280 upgrade

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**

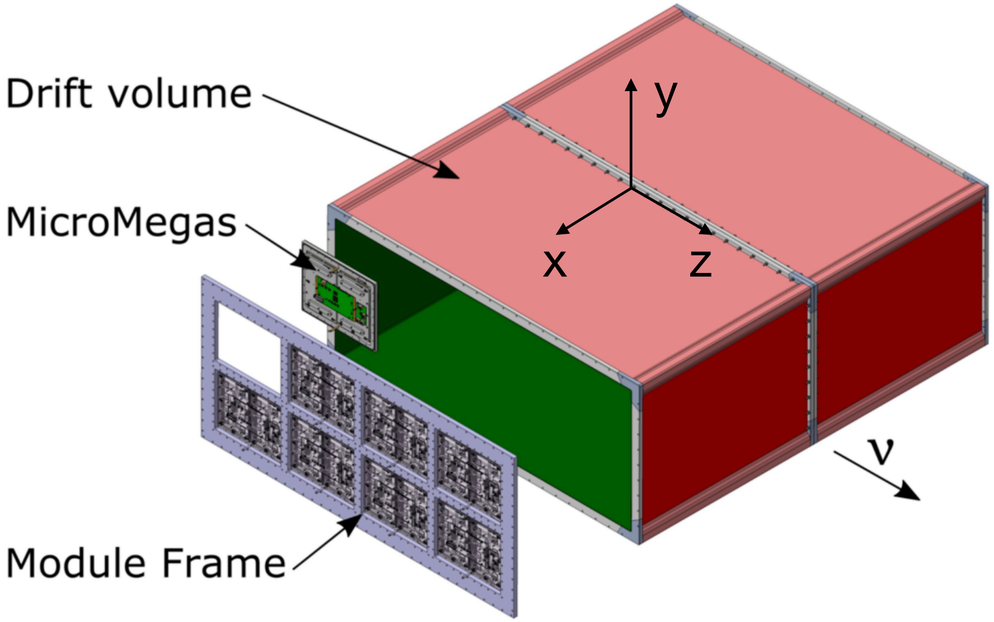




the High-Angle TPC

*EP = End Plate

*ERAM = Encapsulated Resistive Anode Micromegas



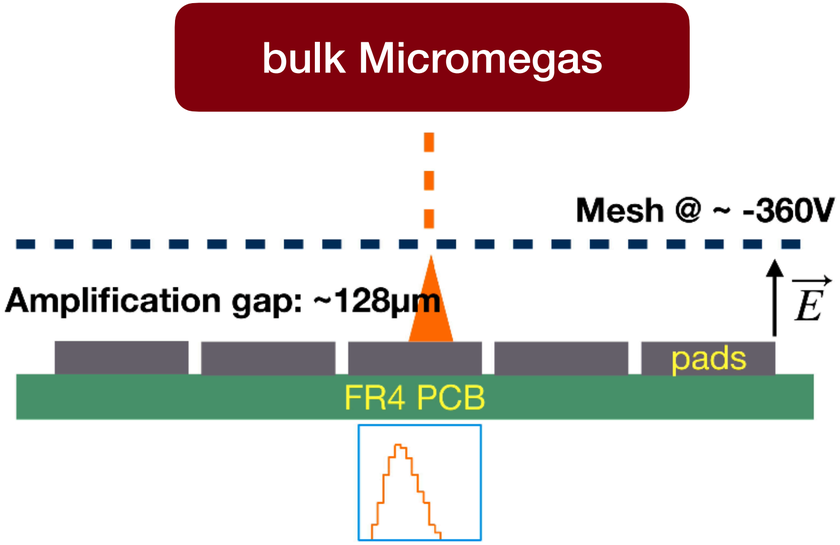
- box-like shape **gaseous detector** ($Ar:CF_4:iC_4H_{10} = 95:3:2$)
- (uniform) $\vec{E}$ in **X-direction**, (uniform) $\vec{B}$ in **X-direction**: charged particles curve in the (Z,Y) plane
- **cathode** in the **middle**: **2 EPs*** for each HAT where the drifted electrons arrive
- **8 ERAMs* for 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

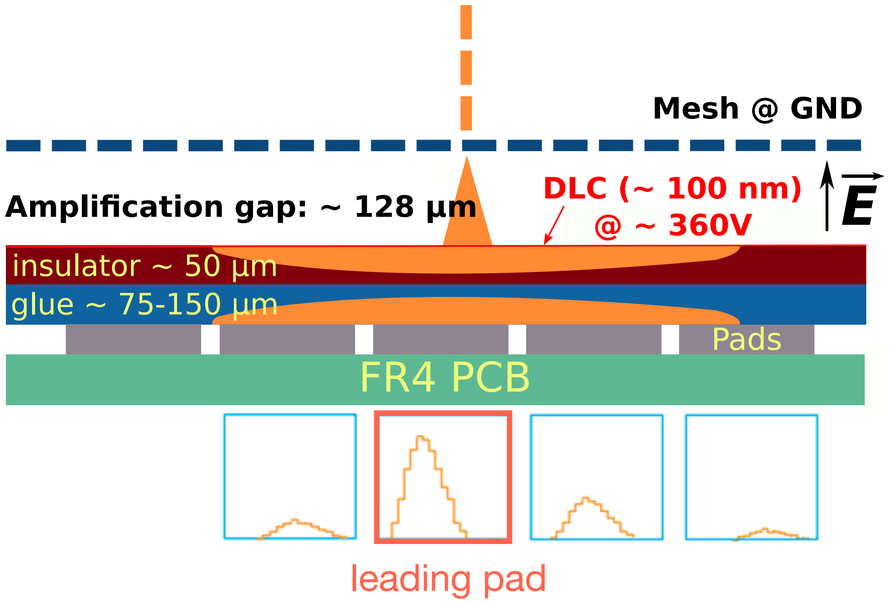
the bulk Micromegas upgrade

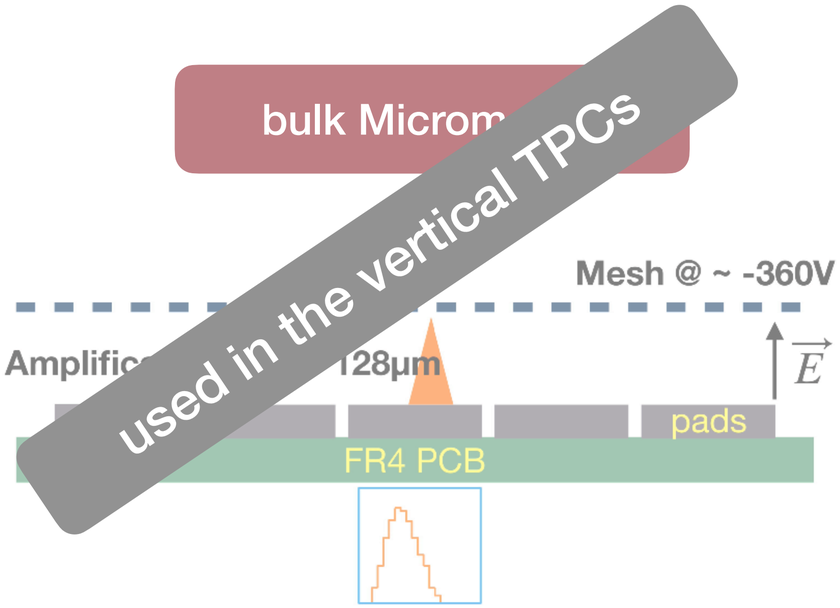
In both **bulk** and **resistive Micromegas**:

- **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 form the **leading pad** and its **neighbours** allows for a **more precise reconstruction** of the **initial particle**
- **spatial resolution** is **improved** compared to bulk Micromegas