Coordination of SIDIS/TMDs studies

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INFN milestone

Internal INFN milestone due to the end of 2025
"Performance studies of PID detectors in the extraction of TMDs."

Generic deliverable:
Realisation of a **plot** to be included in chapter 2 of the TDR.

Why SIDIS?

- Sinergy with the dRICH project: SIDIS process of interest for evaluating dRICH design performances

  Example: study of relevant kynematic distributions, acceptance studies, PID
- Close collaboration with theory groups working on TMDs in Pavia (unpolarized and polarized TMDs) and in Torino (polarized TMDs)
- Experience in spin physics and nucleon structure gained in other experiments

Who?

Several INFN groups expressed interest in the topic:

- **Pavia**: G. Boca, S. Costanza, N. Valle (exp); F. Delcarro, M. Radici, A. Bacchetta (th)
- **Torino**: M. Chiosso, D. Giordano (exp); M. Boglione, E. Nocera, A. Signori (th)
- **Ferrara**: L. Polizzi
- **Salerno**: A. Decaro, S. Pucillo, C. Ripoli
- **Genova**: M. Osipenko
- **Laboratori Nazionali del Sud**: D. Lattuada, Fatemeh Farrokhi
- **Trieste**: A. Bressan, A. Martin
- **Bologna**: F. Bellini
- **Lecce**: G. Chirilli (th)

What?

- First contacts with SIDIS-WG conveners at the end of January (M. Chiosso's slides - 28/01/25)
  - Expressed interest in:
    - Unpolarized TMDs (e+p/D) with identified pions/kaons
    - Sivers (e+p/D) with identified pions/kaons
    - Studies of relevant kynematic distributions, reconstruction efficiency, PID, radiative corrections
- ...but there are other groups involved in these topics since the YR!
- **Conveners' proposal:**
  - concentrate on particle (pion/K/p) identification and subsequent correction
  - need of full likelihoods from all possible PID detectors and all particle hypotheses → **work with the PID detectors and the software/reconstruction group to improve the PID implementation**

What?

- Need to find a **compromise** between the conveners' demands and the focus and timelines of our milestone

- **First steps:**
    - Become familiar with the **software**
    - Become familiar with the **physics** (most of the involved people come from a different field of Physics)
    - Address how to coordinate the INFN physics **milestone** with the needs of the ePIC-SIDIS group
    - Identify the available **manpower** to actively work on the milestone and to **assign tasks** to the various groups/collaborators.

⇨ **SIDIS-Italia kick-off meeting in Pavia (May 13-14, 2025)**

Kick-off meeting

ePIC-Italia SIDIS WG meeting

13–14 mag 2025
Dipartimento di Fisica
Europe/Rome fuso orario

Inserisci il termine di ricerca

- Overview
- Scientific programme
- How to reach us
- Accomodation
- Timetable
- Videoconference link

Contacts

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Scientific programme

The purpose of the SIDIS-Italy group meeting is to offer a **theoretical introduction to SIDIS physics**, primarily intended for newcomers and those who have not yet engaged in an in-depth study of this field.
Additionally, dedicated discussions will focus on identifying and prioritizing the most relevant observables for SIDIS physics in the context of the **early science** phase.

The meeting will also address how to coordinate the ePIC-Italy physics **milestone** with the needs of the ePIC-SIDIS group.
Another objective of the meeting is to identify the available **manpower** to actively work on the milestone and to **assign tasks** to the various groups/collaborators.

Finally, during this meeting, we would like to organize a **'hands-on'** session dedicated to the analysis of the ePIC software, aimed at helping novice analysts retrieve relevant information about the observables of interest within the code.

Kick-off meeting

SIDIS-Italia kick-off meeting in Pavia (May 13-14, 2025)

https://agenda.infn.it/event/46977/

Hybrid meeting, with participants both in person and online.

- **Theoretical introduction** to SIDIS physics
- Dedicated **discussions** focused on identifying and prioritizing the most relevant observables for SIDIS physics in the context of the **early science** phase
- Operative **discussion** on the milestone
- **Hands-on session** dedicated to the analysis of the ePIC software, aimed at helping novice analysts retrieve relevant information about the observables of interest within the code

How is the work proceeding?

Since the kick-off meeting:

- Discussions with **Umberto Tamponi** and **Chandra** to better understand the current status of the PID system:
  - No complete PID algorithms based on likelihoods are available yet – only **lookup tables** exist.
  - This makes PID performance studies more complex, as we **cannot manually modify the lookup tables**.
- Familiarized ourselves with the code provided by Lorenzo
- Attempted to create some plots
- Weekly meeting (Thursday @ 10:00) https://agenda.infn.it/category/2234/
- Contacts:
  - Mailing list (epic-italia-physics-sidis@lists.infn.it)
  - Mattermost channel

Work plan

In order to assess the impact of Particle Identification (PID) performance on the extraction of TMDs, we propose to perform **systematic studies of PID performance** by **manipulating contamination levels a posteriori** and repeating the analysis accordingly.

Instead of relying on existing lookup tables, we simulate varying levels of PID performance **by modifying particle contamination levels** (e.g. pion-to-kaon, kaon-to-proton misID rates). **How?**

1. Define baseline performance from current lookup tables.

2. Inject controlled variations in PID contamination rates.

3. Repeat the full SIDIS analysis chain to observe the effect on key observables (e.g. multiplicities, asymmetries).

4. Compare results to evaluate **sensitivity of TMD extraction** to PID performance.

Work plan

Expected outcome:
a set of performance-driven plots showing the relationship between PID quality and the stability of TMD observables.

Moreover, **Salvatore suggested** checking the **detector performance requirements** defined during the Yellow Report phase

Work plan

η	Nomenclature			Tracking					Electrons and Photons			$\pi/K/p$		HCAL		Muons
				Resolution σ_p/p[GeV/c]	max X/X_0	min p_T	transverse pointing $dca(xy)$, p_T[GeV/c]	longitudinal pointing $dca(z)$, p_T[GeV/c]	Resolution σ_E/E[GeV]	PID	$E_{\min}$	Momentum range	Separation	Resolution σ_E/E[GeV]	$E_{\min}$	
<-4.6	↓ p/A	Far Backward Detectors	low-Q^2 tagger													
-4.6 to -4.0				Not Accessible												
-4.0 to -3.5				Reduced Performance												
-3.5 to -3.0		Central Detector	Backward Detector	$0.2\% * p$ $\oplus 5\%$	$< 5\%$	70 MeV/c to 150 MeV/c	8	9	$1\%/E$ $\oplus 2.5\%/\sqrt{E}$ $\oplus 1\%$	π supp. up to 10^4	20 MeV	<10 GeV/c	$> 3\sigma$	$50\%/\sqrt{E}$ $\oplus 10\%$	500 MeV	18
-3.0 to -2.5							8	9								18
-2.5 to -2.0				$0.04\% * p$ $\oplus 2\%$			40 µm/p_T $\oplus$10 µm	100 µm/p_T $\oplus$20 µm								18
-2.0 to -1.5									$2\%/E$ $\oplus(4-8)\%/\sqrt{E}$ $\oplus 2\%$	π supp. up to $10^3 - 10^2$	50 MeV					18
-1.5 to -1.0																18
-1.0 to -0.5			Barrel	$0.04\% * p$ $\oplus 1\%$		200 MeV/c	30 µm/p_T $\oplus$5 µm	30 µm/p_T $\oplus$5 µm	$2\%/E$ $\oplus(12-14)\%/\sqrt{E}$ $\oplus 2-3\%$	π supp. up to 10^2	100 MeV	<6 GeV/c		$100\%/\sqrt{E}$ $\oplus 10\%$		18
-0.5 to 0.0																18
0.0 to 0.5																18
0.5 to 1.0																18
1.0 to 1.5			Forward Detector	$0.04\% * p$ $\oplus 2\%$		70 MeV/c to 150 MeV/c	40 µm/p_T $\oplus$10 µm	100 µm/p_T $\oplus$20 µm	$2\%/E$ $\oplus(4-12)\%/\sqrt{E}$ $\oplus 2\%$	3σ e/π up to 15 GeV/c	100 MeV	<50 GeV/c		$50\%/\sqrt{E}$ $\oplus 10\%$		18
1.5 to 2.0																18
2.0 to 2.5							8									18
2.5 to 3.0				$0.2\% * p$ $\oplus 5\%$			8	9								18
3.0 to 3.5							8	9								18
3.5 to 4.0				Reduced Performance												
4.0 to 4.6				Not Accessible												
>4.6	↑ e	Far Forward Detectors	Proton Spectrometer													
			Zero Degree Neutral Detection													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		18

Work plan

Expected outcome:
a set of performance-driven plots showing the relationship between PID quality and the stability of TMD observables.

Moreover, **Salvatore suggested** checking the **detector performance requirements** defined during the Yellow Report phase

- Do we still meet these original performance criteria?
- How sensitive are the **physics observables** to variations in these criteria?

- Use the Yellow Report requirements as a **reference point**.
- Vary individual detector performance parameters and observe the impact on:
  - PID efficiencies and purities
  - Final SIDIS observables (e.g. asymmetries, cross sections)

This study will run **in parallel** with the main TMD extraction analysis.

Status

Proposal submitted to the conveners:

- they think it is reasonable
- it will be discussed at the next SIDIS-WG meeting (July 1, 2025)

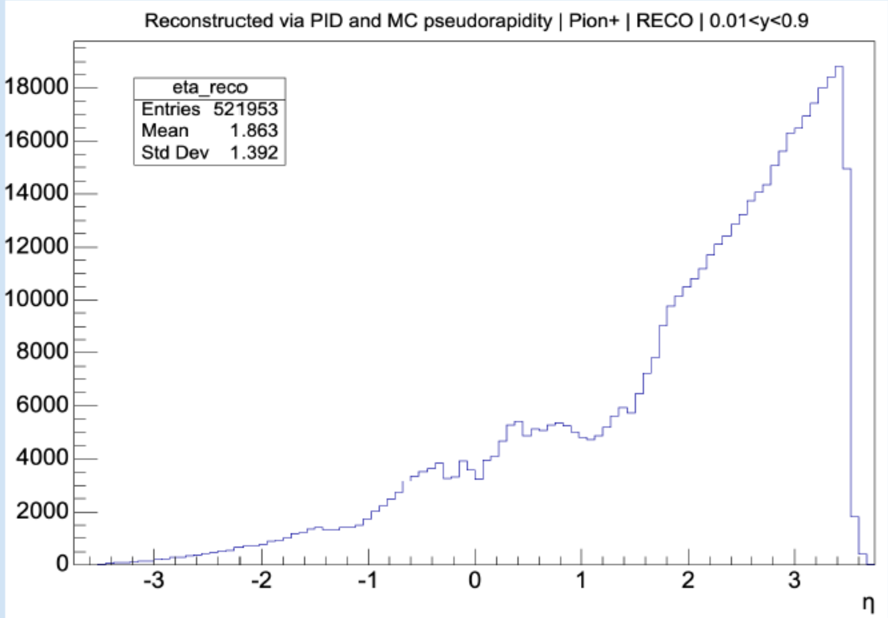
Let's say ... 30% is done

- **First plot** on kinematic variables (π^+ distributions, reconstruction efficiencies and contaminations for SIDIS analyses) produced by Lorenzo
- Preliminary results will be presented at the next SIDIS-WG meeting

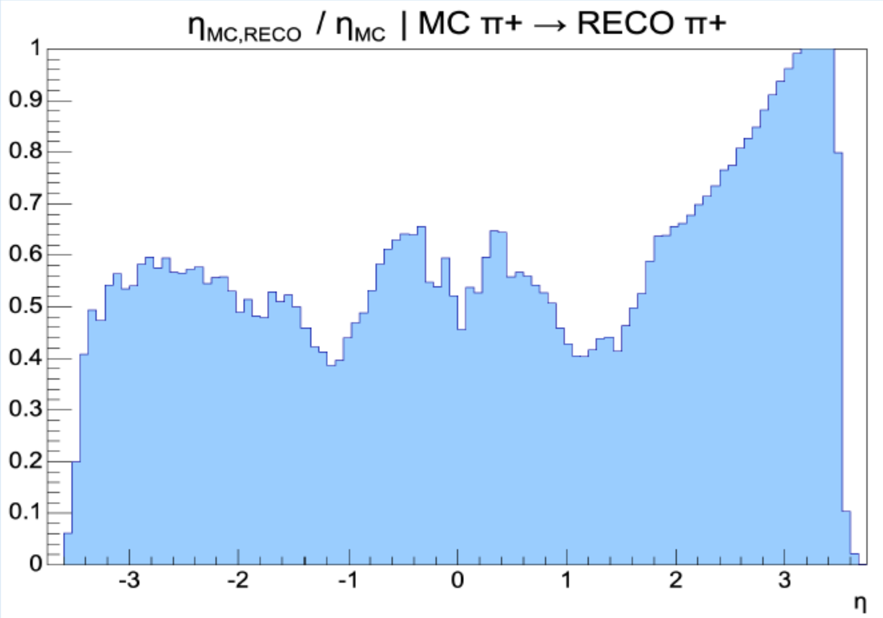
First results – L.Polizzi

PSEUDORAPIDITY EFFICIENCY

Pseudorapidity (η) provides important information about the spatial distribution of the process and highlights the performance of the different types of ePIC detectors.



Pseudorapidity distribution



Efficiecy

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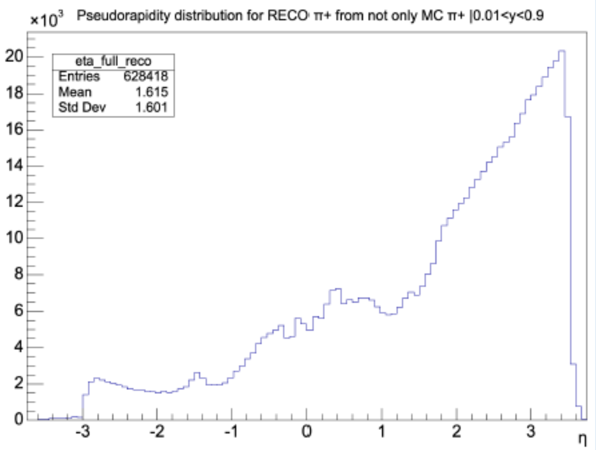
First results – L.Polizzi

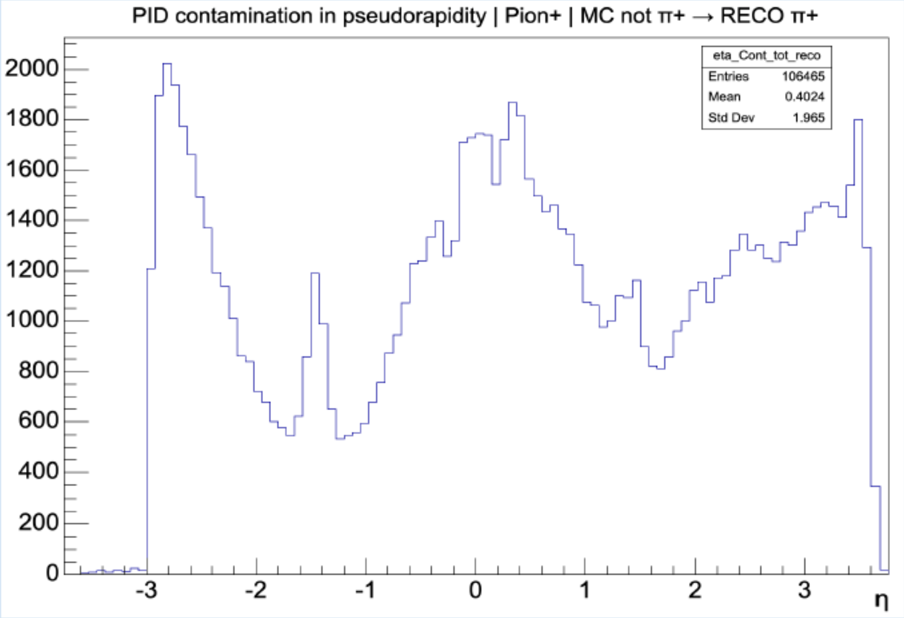
PSEUDORAPIDITY CONTAMINATION

Observing the π^+ reconstruction, almost **17%** of the identifications are source of data contaminations.

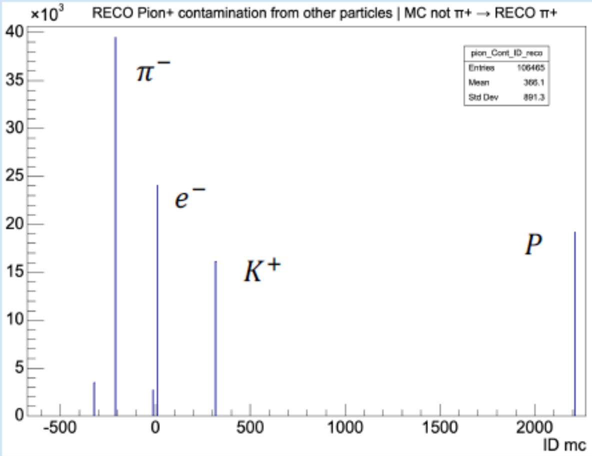
π^+ 37.1% e^- 22.6%
K^+ 15.1% P 18.1%



Pseudorapidity distribution



η distribution of reconstructed contaminated data



Contamination sources

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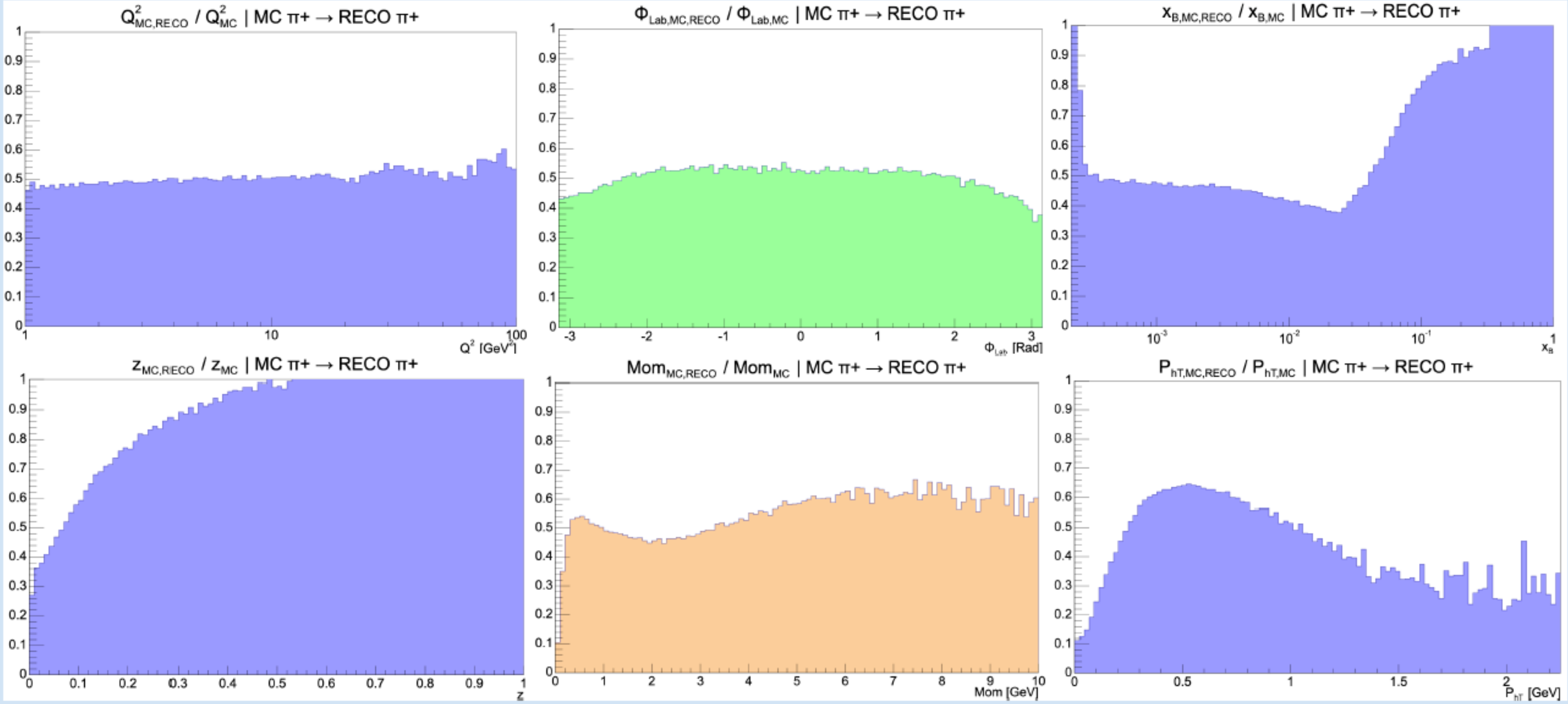
First results – L.Polizzi

KINEMATIC EFFICIENCY

From MC and RECO production we observe that the total efficiecy of MC π^+ correctly reconstructed as π^+ is about to $\mathbf{49.1\%}$.

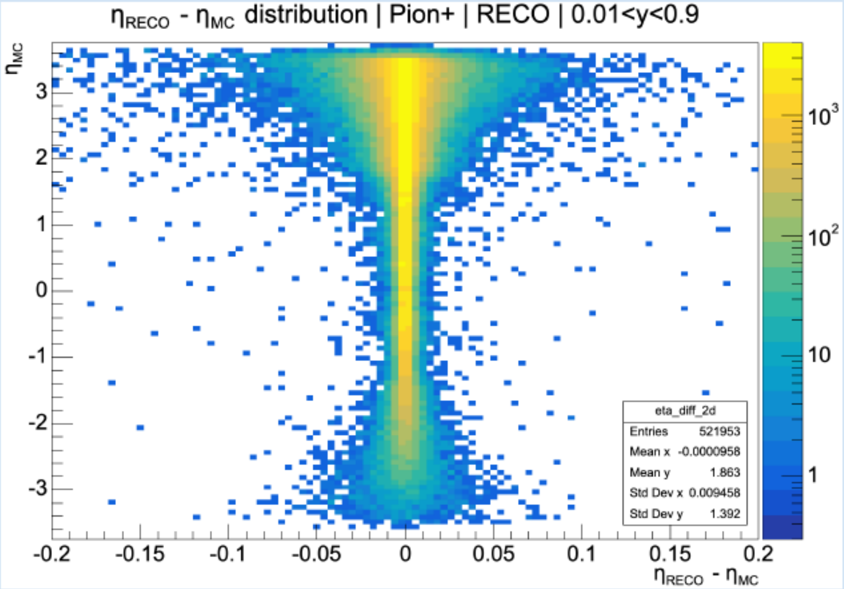


First results – L.Polizzi

RECONSTRUCTION PRECISION

The **reconstruction** performance shows **slight underestimation** behavior of the main variables such as: $\boldsymbol{x_B}, \boldsymbol{Q^2}, \boldsymbol{z}, \boldsymbol{P_h}$ while it shows an **overestimation** only for P_{hT}. The tracking system provides a **nearly perfect** reconstruction of $\boldsymbol{\eta}$.

	$\Delta_{mean}(RECO - MC)$	σ_{STD}
η	-9.6×10^{-5}	9.5×10^{-3}
x_B	-0.0136	0.0348
Q^2	-0.1024	0.3406
z	-0.0203	0.0535
P_h	-0.0315	0.2281
P_{hT}	$+0.0264$	0.1411



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Next steps

Work in progress:

- Produce similar plots for other particle species
- Become more confident with the software
- Divide the tasks among the group
- Extract meaningful parameters for the cross section and TMDs studies
- Repeat the studies with different contamination levels