



SAPIENZA
UNIVERSITÀ DI ROMA



CENTRO RICERCHE
ENRICO FERMI

Analysis status

FOOT General Meeting
25/06/2024

Marco Toppi, for the analysis crew



FOOT campaigns to analyze

Electronic setup					
Campaign	Beams	Energy [MeV/u]	Targets	Detectors	
GSI 2019	O	400	C	SC, BM, TW	
GSI 2021	O	200, 400	C, C ₂ H ₄	SC, BM, VT, MSD, TW	
HIT 2022	He	100, 140, 200, 220	C	SC, BM, MSD, TW, CALO	
CNAO 2022	C	200	C	SC, BM, VT, MSD, TW, CALO	
CNAO 2023	C	200	C, C ₂ H ₄	Full, magnets	

Emulsions setup				
Campaign	Beam	Energy [MeV/u]	Targets	
GSI 2019	O	200, 400	C, C ₂ H ₄	
GSI 2020	C	700	C, C ₂ H ₄	
CNAO 2023	C	221	C, C ₂ H ₄	

CNAO 2017 setup				
Campaign	Beam	Energy [MeV/u]	Targets	Angles
CNAO 2017	C	115,153, 221, 281, 353	C, C ₂ H ₄ , PMMA	32°, 60°, 90°

Ongoing Analysis: status @ Trento GM

Electronic setup						
Campaign	Beams	Energy [MeV/u]	Targets	Detectors	Status	
GSI 2019	O	400	C	SC, BM, TW	✓	
GSI 2021	O	200, 400	C, C ₂ H ₄	SC, BM, VT, MSD, TW	✓	
HIT 2022	He	100, 140, 200, 220	C	SC, BM, MSD, TW, CALO	✗	
CNAO 2022	C	200	C	SC, BM, VT, MSD, TW, CALO	✗	
CNAO 2023	C	200	C, C ₂ H ₄	Full, magnets	✗	

Emulsions setup					
Campaign	Beam	Energy [MeV/u]	Targets	Status	
GSI 2019	O	200, 400	C, C ₂ H ₄	✓	
GSI 2020	C	700	C, C ₂ H ₄	✗	
CNAO 2023	C	221	C, C ₂ H ₄	✗	

CNAO 2017 setup					
Campaign	Beam	Energy [MeV/u]	Targets	Angles	Status
CNAO 2017	C	115,153, 221, 281, 353	C, C ₂ H ₄ , PMMA	32°, 60°, 90°	✓

Ongoing Analysis

Campaign	setup	technique	physics	Energy [MeV/u]	Calo	who	MC	Data	paper
GSI 2021	electronic	Global tracking	16O+C fragmentation (2<Z<8)	400	-	Giacomo Ubaldi	✓	✗	-
GSI 2021	electronic	SC+TOF	16O+C fragmentation (2<Z<8)	400	-	Riccardo Ridolfi	✓	✓	In progress
GSI 2021	electronic	Global tracking	Alpha clustering (from 16O)	200	-	Alice, Giuseppe, Silvia	✓	✗	-
GSI 2019	emulsion	S1+S2	16O+C,C2H4 fragmentation	200	-	Giuliana Galati	✓	✓	In progress
GSI 2019	emulsion	S1+S2	Alpha clustering (from 16O)	200	-	Vincenzo Boccia	✓	✓	-
CNAO 2023	electronic	Global tracking	12C+C fragmentation (2<Z<6)	200	Yes	RobZ, Luana Testa	✓	✓	-
CNAO 2017	Plastic scintillators+LYSO	ToF+Ekin	12C fragmentation at large angles (p,d,t)	115,153, 221, 281, 353	-	Ilaria Mattei	✓	✓	In progress

“Future” Analysis

Campaign	setup	technique	physics	Energy [MeV/u]	Calo	who	MC	Data
HIT2022	electronic	Global tracking	4He+C->p,d,t,3He	100,140,200,220	Yes	Alessandro, Francesca, Tino, Aafke, Matteo M, Lorenzo Pierfederici	✗	✗
CNAO2022	electronic	Global tracking	12C+C	200 (12C)	-	-	✗	✗
GSI 2021	electronic	no tracking	16O+C,C2H4→H+16O (inverse)	400 (16O)	-	Matilde Dondi + Riccardo	✓	✓
GSI 2021, CNAO2023	electronic	Global tracking	16O+C,C2H4→H+16O (inverse)	200 (12C) 400 (16O)	-	-	✗	✗
CNAO 22-23	electronic	Global tracking	12C frag with Mass identification with calo	200	Yes	-	✗	✗
GSI 2019	emulsion	S1+S2+S3	16O+C,C2H4 fragmentation with momentum rec	200	-	Giuliana Galati	✓	✗

Status @ Trento GM

Campaign	BM	VTX / IT	MSD	TW (+ SC)	Calo	Alignment	Full MC	DAQ synchronization/cleaning
GSI 2021	✓	✓	Pedestal Eta function	Calibration Eloss/Tof ZID Positions along bar	-	✓	✓	✓
HIT 2022	✓	-	Pedestal Eta function	Calibration Eloss/Tof ZID Positions along bar	Calibration	✓	✓	✓
CNAO 2022	✓	✓	Pedestal Eta function	Calibration Eloss/Tof ZID Positions along bar	Calibration	✗	✓	✗
CNAO2023 (12C_200_2023 v2)	✓	✓	Pedestal Eta function	Calibration Eloss/Tof ZID Positions along bar	Calibration	✓	✓	✓
	Yun	Chris	Benedetto, Gianluigi, Leonello, Lucia	Aafke, Giacomo, Marco, Matteo M, RobZ, Tino	Alessandro, Benedetto, Francesca, Piergiorgio	Yun	Giuseppe, Silvia	Riccardo, Mauro

Status of the needed inputs / calibrations of each campaign

Campaign	BM	VTX / IT	Pile-up / vertexing	MSD	TW (+ SC)	Calo	Alignment	Full MC (*)	DAQ synchronization/cleaning
GSI 2021	✓	✓	✓	Pedestal Eta function	Calibration $\Delta E/Tof$ ZID Positions along bar	-	✓	✓	✓
HIT 2022	✓	-	-	Pedestal Eta function	Calibration $\Delta E/Tof$ ZID Positions along bar	Calibration	✓	✓	✓
CNAO 2022	✓	✓	✓	Pedestal Eta function	Calibration $\Delta E/Tof$ ZID Positions along bar	Calibration	✗	✓	✗
CNAO 2023	✓	✓	✓	Pedestal Eta function	Calibration $\Delta E/Tof$ ZID Positions along bar	Calibration	✓	✓	✓
	Yun	Chris	Chris, Luana Testa, Marco	Benedetto, Gianluigi, Leonello, Lucia, RobZ	Aafke, Giacomo, Marco, Matteo M, RobZ, Tino	Alessandro, Benedetto, Francesca, Piergiorgio	Yun	Giuseppe, Silvia	Riccardo, Mauro

(*) New MC simulation with passive materials produced for GSI2021 and CNAO2023 campaigns (Giuseppe and Sivia today'talk)

Reconstruction in GSI2021, CNAO2022-2023

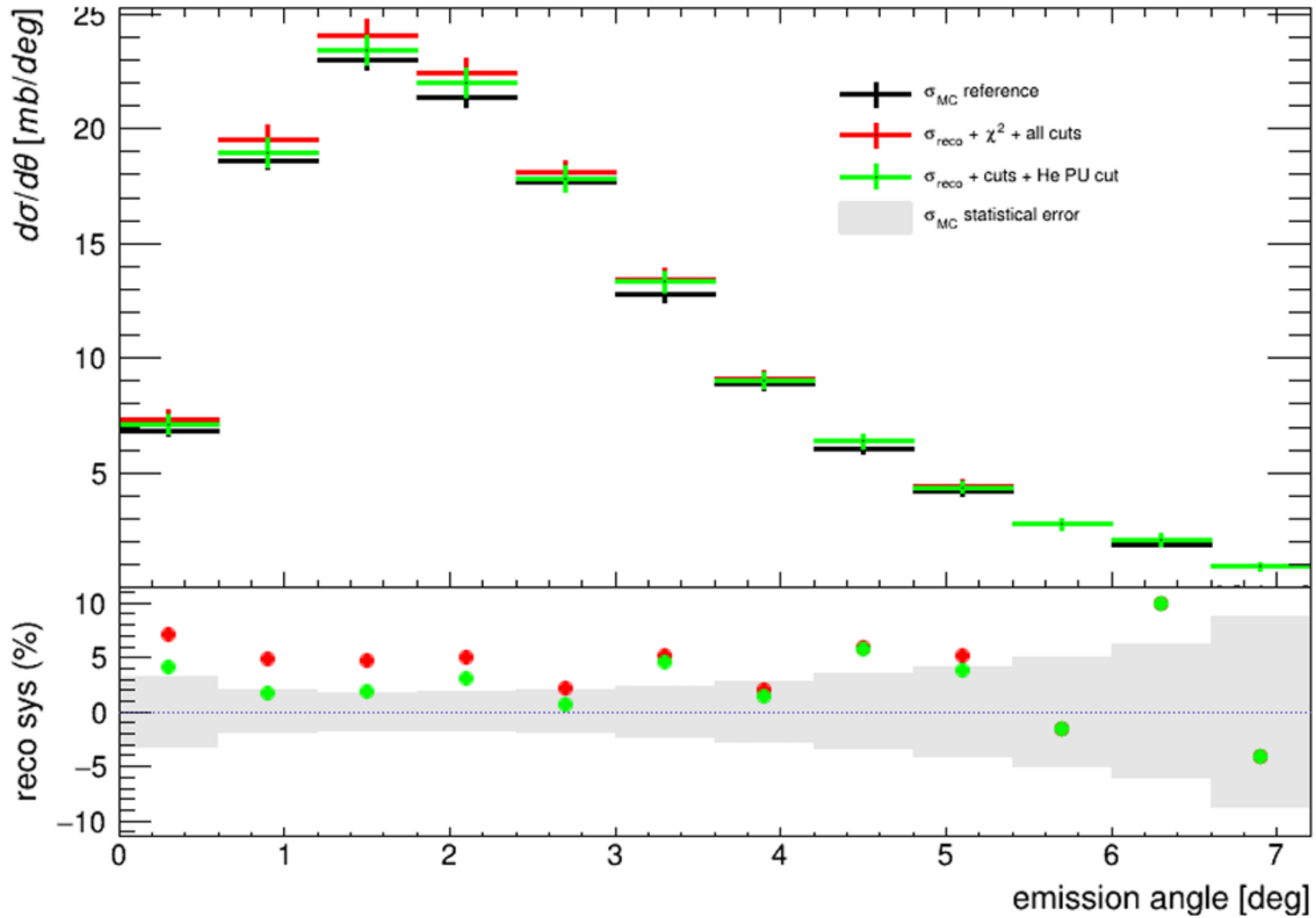
- Common selections for global tracks which provide closure test of the **reconstructed elemental (Z) cross section** wrt the true one with a precision $\sim 5\%$ for full setup **with and without magnetic field**. No calo included.
- GiacomoU and RobZ are working on a class in shoe implementing such selection needed for most of the analysis performed in these campaigns (see alpha clustering talk by Giuseppe):

- **Track quality** (selection on χ^2/p -value and track residuals)
- **1 BM track**
- **1 valid vertex inside the TG matched with BM** \rightarrow fragmentation + remove pile up
- **N tracks in vtx > 1** \rightarrow only fragmentation, remove most of the pre target fragmentation and primaries
- **Rejection of global tracks with the same TW point associated** \rightarrow remove mostly events of He+He in same TW bar cross
- **Rejection of events with N global tracks \neq N TWpoints** \rightarrow remove out of target fragmentation + TW inefficiencies

Important implications

- **Rejection of background** (out of target, combinatorial and cross feed (mainly He+He->Li)) **together with a high purity of the surviving global tracks (and lower efficiency)**
 - no need to implement anymore background subtraction technique from “no target” data

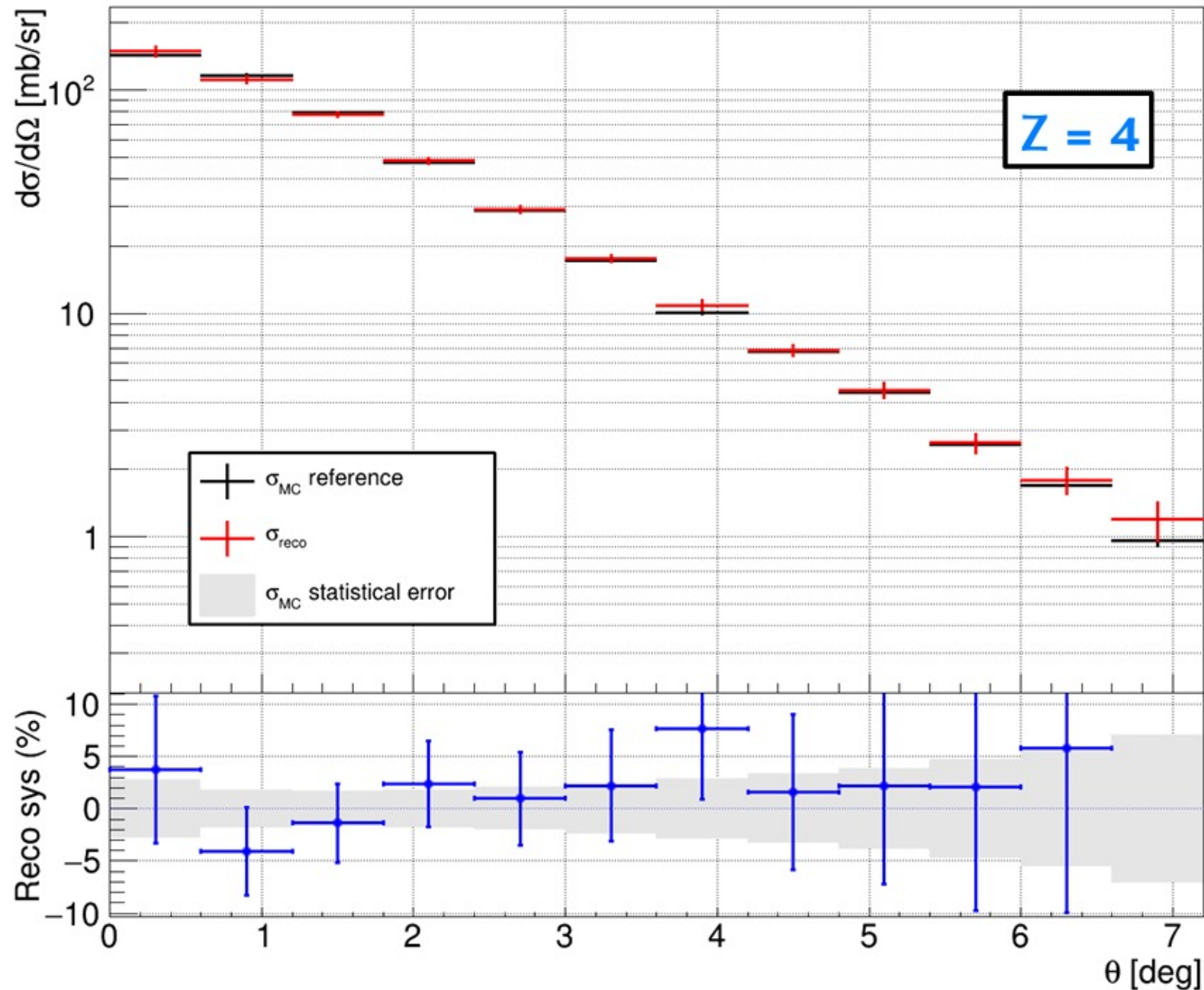
Z=3 differential cross section



GSI 2021

O+C -> Li+X

GiacU: PM 02/2024



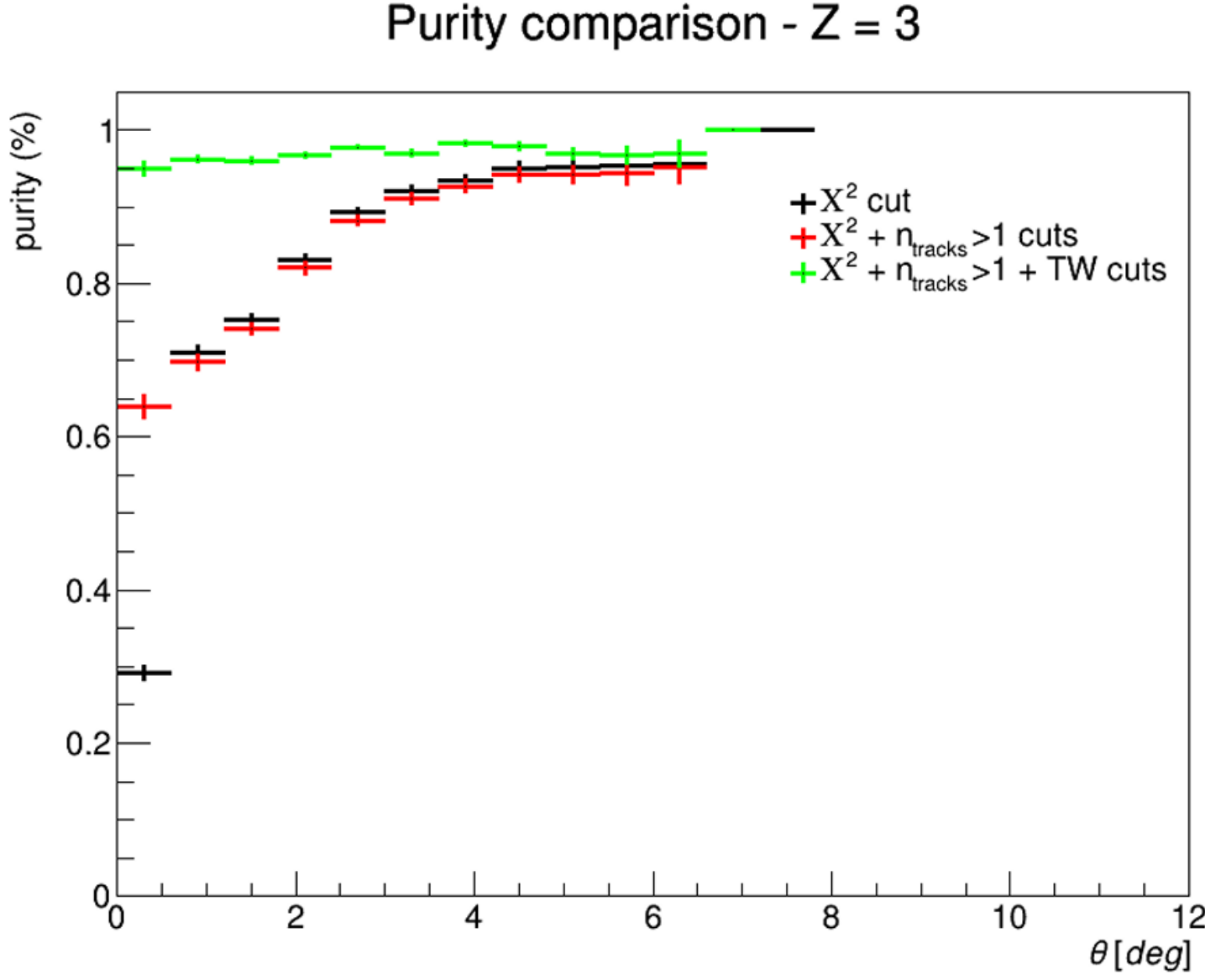
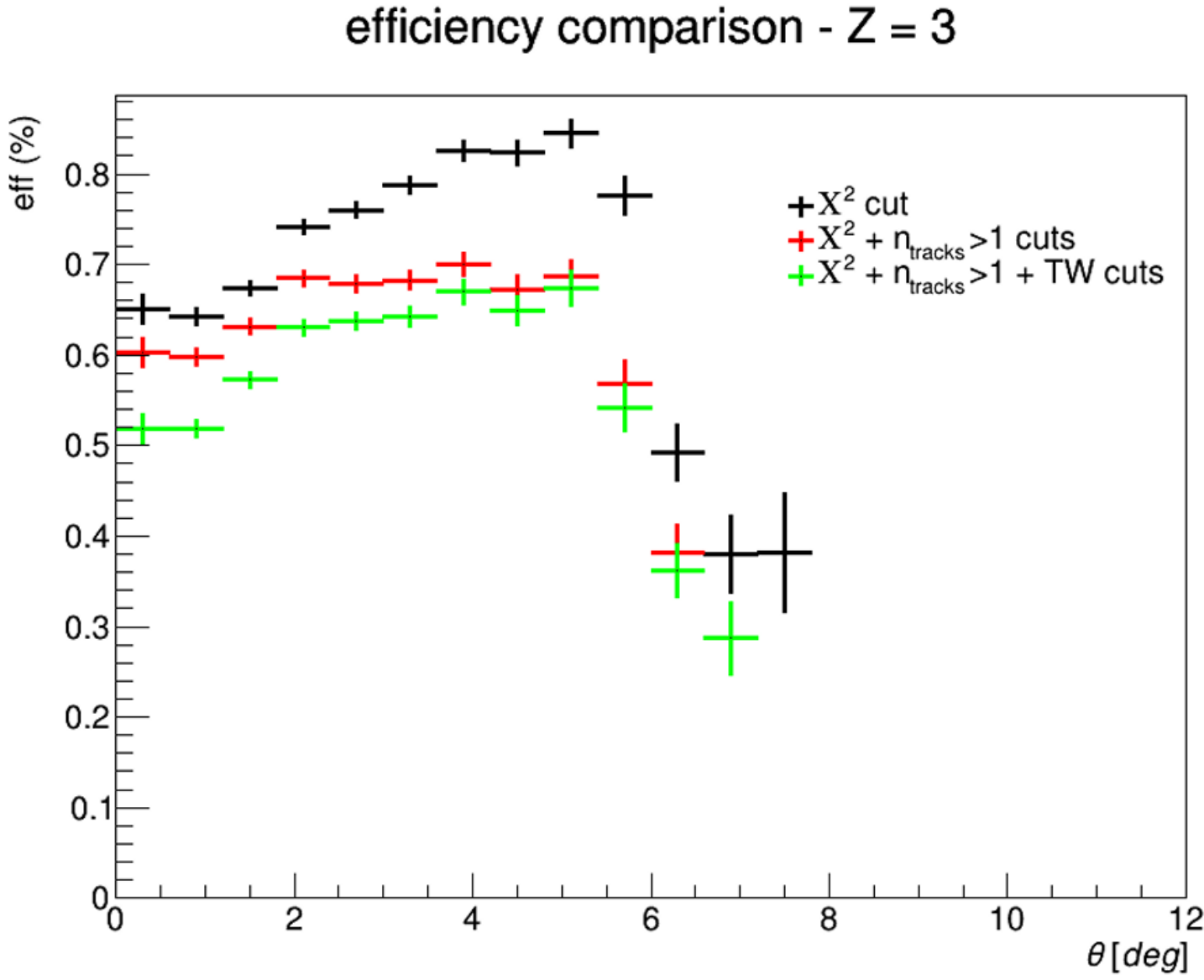
CNAO 2023

C+C -> Be+X

RobZ: PM 02/2024

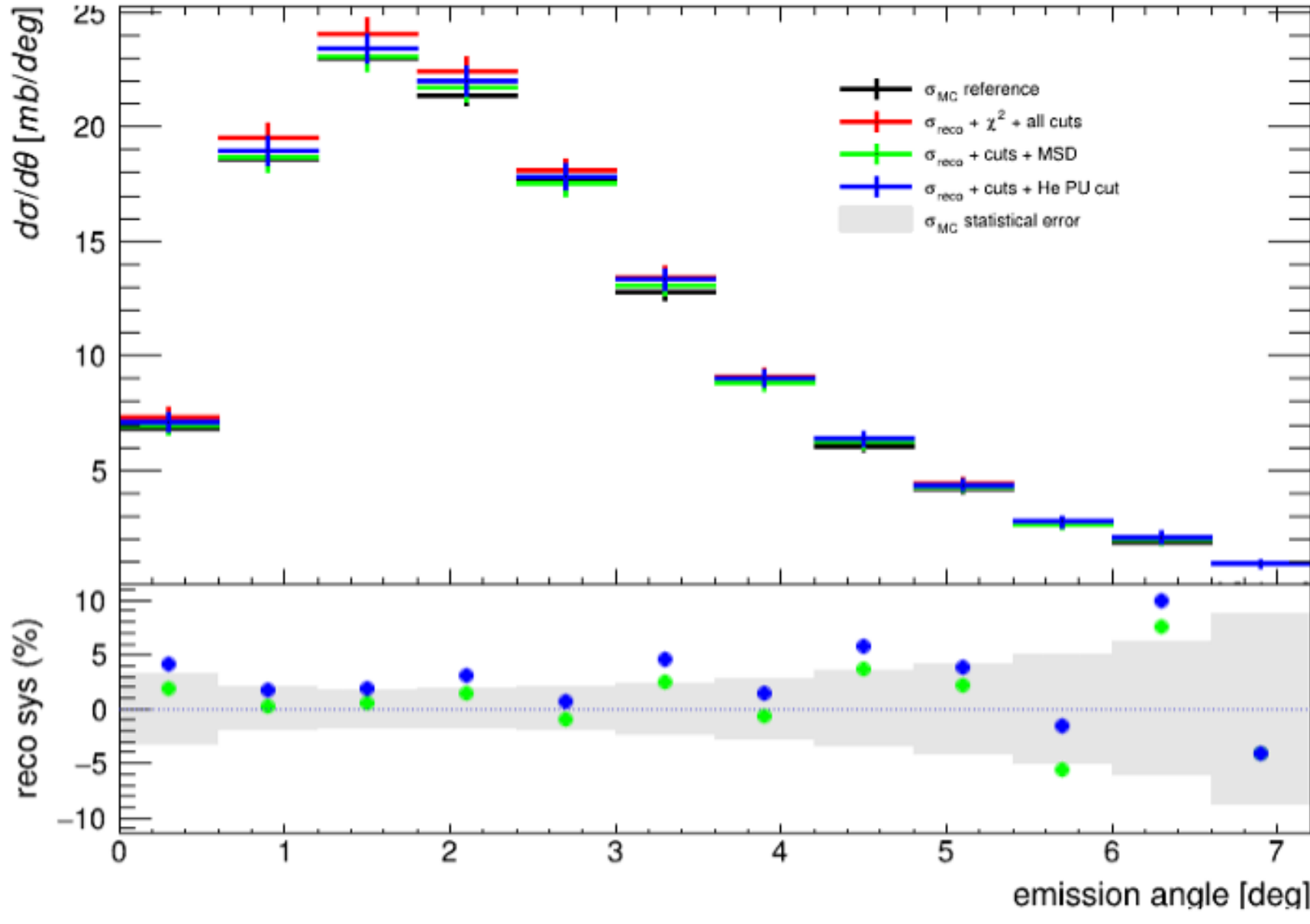
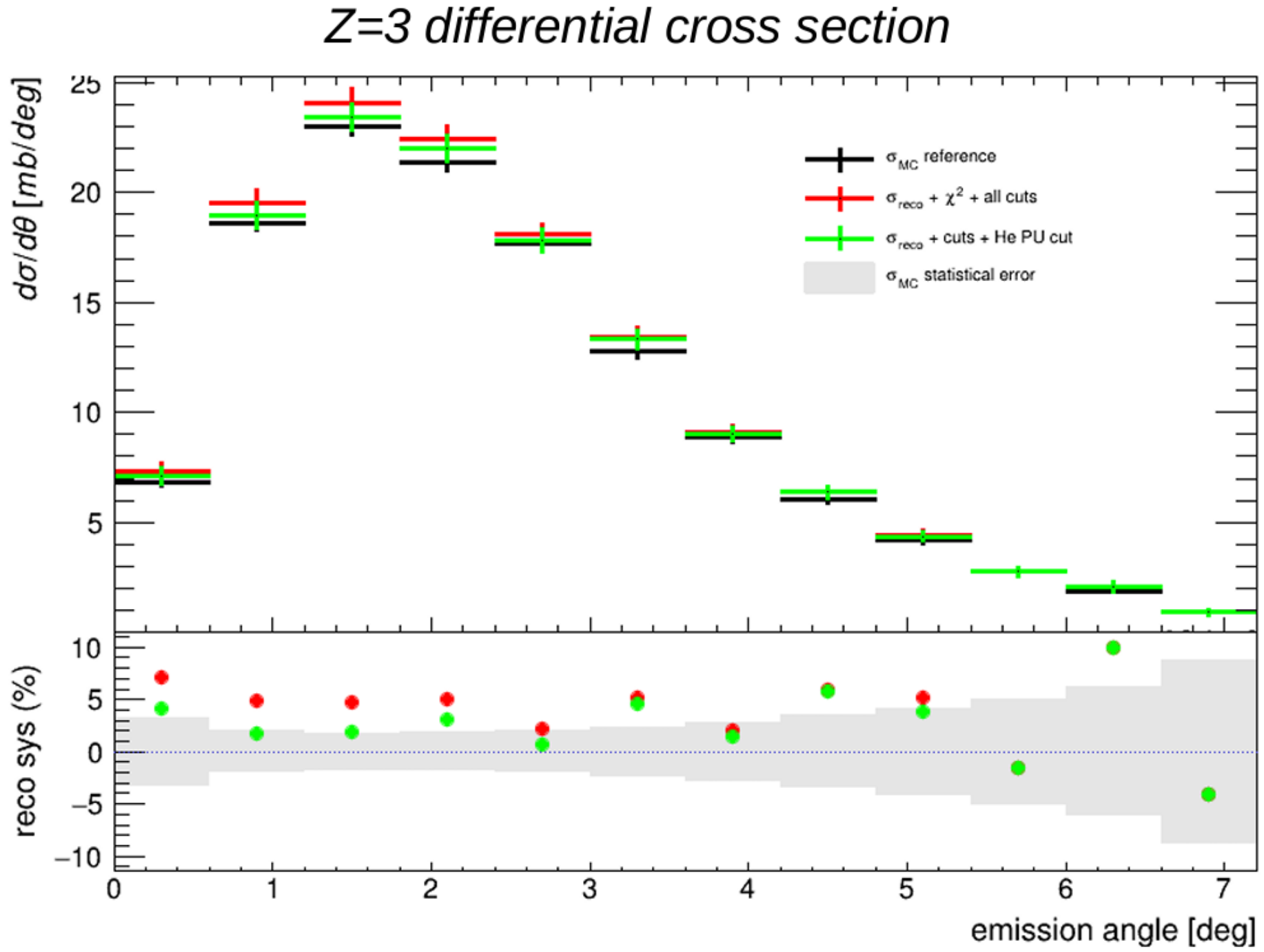
Important implications

- **A robust fragment Z identification**, as the one reached within GSI 2021 analysis, **allows to implement the inverse kinematic approach to measure H+O XS**. We can implement an integrated cross section for the process H+O for the different fragment Z with GSI2021 data



Important implications

- Still room for detector reconstruction improvement (see VTX cluster size and MSD eta function useful for ghost removal and ZID algorithm, IT impact). But **now we can estimate the impact of their implementation in the XS** and evaluate it in terms of manpower / time for publication



Here studied by GiacU the impact of the “MC true” charge from MSD on XS → talk from RobZ today about MSD Eloss calib

What is still missing?

- In MC no pile up effects in VD and IT, no detector effects (noise, cluster sizes, threshold and efficiency tuned from data) for most of the trackers...so the thing get worse, and we still need to study the impact of this effects in the final cross section
- Isotopic cross sections in CNAO2023 MC
- Pile up in VT/IT, high rates effects (+ pile-up studies in MC to better understand our capability in rejecting it and to estimate a rejection efficiency)
- MSD eta function / charge equalization and implementation of ZID and ghost removal
- MSD and VTX / IT efficiency / threshold study in data and tuning in MC
- Tuning of the experimental resolutions in MC for every measured quantity not completed yet
- Effects of misposition/rotation of the magnetic field / alignment with the full detector
- Systematics on the implemented algorithms, geometry, analysis techniques
- Further experimental effects correction (i.e. Tof worsening at CNAO 2023 → see GiacTraini's talk in last GM)



Performances, MC tuning with data

	BM	VTX / IT	MSD	TW (+SC)	Calo	Global Tracking
Performances data/MC comparison	<ul style="list-style-type: none"> Track Efficiency (Data/MC) and Purity Residuals/Pulls Noise Data/MC 	<ul style="list-style-type: none"> Clustering, tracking and vertexing Efficiency and Purity for each Z in angular bins Residual/Pulls for each Z Cluster size for each Z (data/MC) Efficiency wrt sensor position (Data/MC) Dead map, noise Data/MC 	<ul style="list-style-type: none"> Efficiency and Purity for cluster and points for each Z Resolution for cluster and point position Cluster size for each Z (data/MC) Noise Data/MC 	<ul style="list-style-type: none"> Efficiency and Purity for TW points for each Z Resolution in Eloss, Tof and Position for each Z CMM Eloss, Tof and position along the bar for each Z (data/MC) 	<ul style="list-style-type: none"> Efficiency and Purity for clustering for each Z Kinetic energy and position resolution for each Z (data/MC) 	<ul style="list-style-type: none"> Efficiency and Purity for each Z and A in angular and kinetic energy bins Residual/Pulls for each Z Comparison data/MC glb trk outputs Resolution in angle, Ekin, Momentum, Mass
Status	In progress	In progress	In progress	In progress	In progress	In progress
People	Yun	Chris, Giacomo U	Leonello, Benedetto, Alessio, RobZ	Giacomo, Marco, Roberto	Alessandro, Francesca	Roberto, Giacomo U

- We should start to collect plots of detector/FOOT performances and data/MC comparison for each campaign in a repository (Yun created it on git)**
- Useful for having an idea of the status of reconstruction of FOOT and plots ready for conferences / meeting with referee / meeting for funds requests

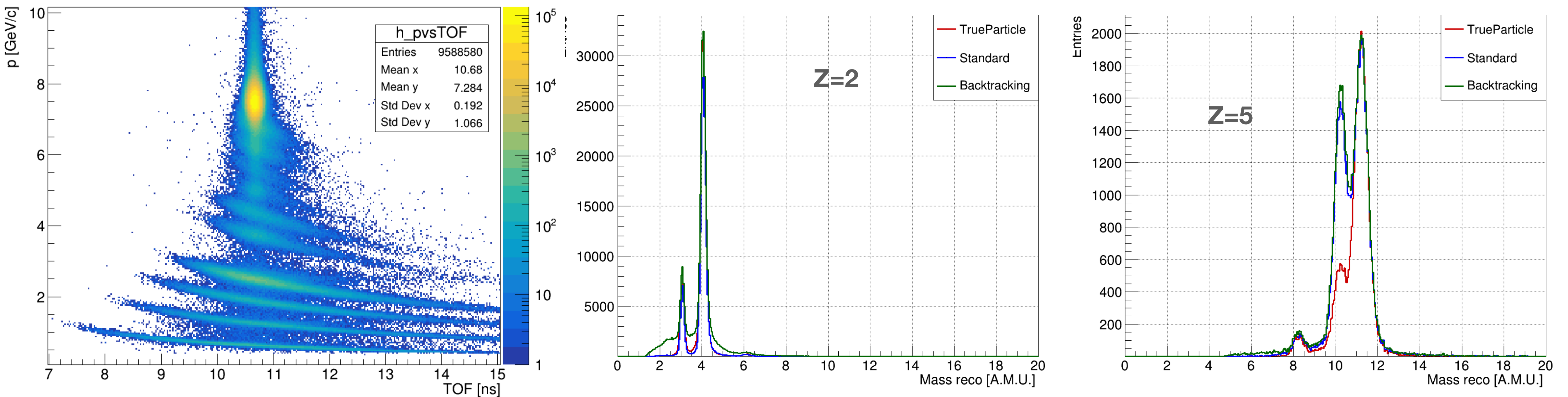
Conclusions 1: FOOT priorities in XS analysis

Priority order set by referee requests:

- ✓ **GSI 2021** (O @ 400MeV/u) data analysis finalization for the electronic setup
- ✓ **GSI 2019** (O @ 200, 400MeV/u) data analysis finalization for the emulsion setup
- ✓ Implementation of a MC closure test for full setup / **CNAO2023** analysis starting from the experience of the GSI2021 analysis and then relative data analysis
- ✓ **HIT 2022** (+ implementation of vertexing with backtracking algorithm)
- ✓ **CNAO2017 setup**
- ✓ **GSI 2021** (O @ 200 MeV/u)
- ✓ **CNAO2022** (C @ 200MeV/u electronic setups)
- ✓ **CNAO2023 and GSI2020** (C @ 200MeV/u and 700 MeV/u emulsion setups)

CNAO2023 MC status

- Preliminary results from RobZ already show good mass separation (resolution of some detector already included) with the full setup and magnetic fields, using the momentum p and ToF reconstruction.
- In next months reply of the work done for GSI 2021 to have a MC closure test for the isotopic fragmentation XS
- Big effort from Giuseppe and Silvia to make the new CNAO2023 simulation data compliant (see magnetic field map)
- A lot of work from RobZ to finally fully exploit the tier1 resources for a fast process of full stat files needed for all the XS analysis → Roberto's talk of today



Courtesy of Roberto Zarrella