Analysis status

FOOT Physics Meeting
07/02/2024

Marco Toppi, for the analysis crew

FOOT campaigns to analyze

We have collected several dataset with different setups: data analysis ongoing / waiting to be analyzed

Electronic setup				
Campaign	**Beams**	**Energy [MeV/u]**	**Targets**	**Detectors**
GSI 2019	O	400	C	SC, BM, TW
GSi 2021	O	200, 400	C, C_2H_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_2H_4	Full, magnets

Emulsions setup			
Campaign	**Beam**	**Energy [MeV/u]**	**Targets**
GSI 2019	O	200, 400	C, C_2H_4
GSI 2020	C	700	C, C_2H_4
CNAO 2023	C	221	C, C_2H_4

CNAO 2017 setup				
Campaign	**Beam**	**Energy [MeV/u]**	**Targets**	**Angles**
CNAO 2017	C	115,153, 221, 281, 353	C, C_2H_4, PMMA	32°, 60°, 90°

Ongoing Analysis

Campaign	setup	technique	physics	Energy [MeV/u]	Calo	who	MC	Data
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	✓	✓
GSI 2019	emulsion	S1+S2	16O+C,C2H4 fragmentation	200	-	Giuliana Galati	✓	✓
GSI 2019	emulsion	S1+S2	Alpha clustering (from 16O)	200	-	Vincenzo Boccia	✓	✓
CNAO 2023	electronic	Global tracking	12C+C fragmentation (2<Z<6)	200	No	RobZ	✓	✗
CNAO 2023	electronic	Global tracking	Alpha clustering (from 12C)	200	No	Alice, Giuseppe, Silvia	✓	✗
CNAO 2017	Plasti scintillators +LYSO	ToF+Ekin	12C fragmentation at large angles (p,d,t)	115,153, 221, 281, 353	-	Ilaria Mattei	✓	✓

“Future” Analysis

Campaign	setup	technique	physics	Energy [MeV/u]	Calo	who	MC	Data
GSI 2021, CNAO2023	electronic	Global tracking	16O+C,12C+C->protons	200 (12C) 400 (16O)	-	Giacomo Ubaldi	✓	✗
GSI 2021, CNAO2023	electronic	Global tracking	16O+C,C2H4→H+16O (inverse)	200 (12C) 400 (16O)	-	-	✗	✗
HIT2022	electronic	Global tracking	4He+C->p,d,t,3He	100,140,200,220	Yes	Alessandro, Francesca, Tino	✗	✗
CNAO 2023	electronic	Global tracking	12C frag with Mass identification with calo	200	Yes	-	✗	✗
GSI2021	electronic	Global tracking	Alpha clustering (from16O)	200	No	-	✗	✗
GSI 2019	emulsion	S1+S2+S3	16O+C,C2H4 fragmentation with momentum rec	200	-	Giuliana Galati	✓	✗

Status of the needed inputs / calibrations of each campaign

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	✓	✓	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

- **Missing/inclomplete calibration / input from detectors for GSI2021/CNAO2023 campaigns from now on are urgent because stuck or slow the data analysis**

Performances, MC tuning with data

	BM	VTX / IT	MSD	TW (+SC)	Calo	Global Tracking
Performances data/MC comparison	• Track Efficiency (Data/MC) and Purity • Residuals/Pulls • Noise Data/MC	• Clustering, tracking and vertexing • Efficiency and Purity for each Z in angukar bins • Residual/Pulls for each Z • Cluster size for each Z (data/MC) • Efficiency wrt sensor position (Data/MC) • Dead map, noise Data/MC	• 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	• 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)	• Efficiency and Purity for clustering for each Z • Kinetic energy and position resolution for each Z (data/MC)	• 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, Yun	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 is working on that)**
- Useful for having an idea of the status of reconstruction of FOOT and plots ready for conferences / meeting with referee / meeting for funds requests

What have we learned so far?

From my talk to the last GM:

- **The GSI 2021 analysis is our first testing-bench** (see Riccardo and Giacomo Ubaldi talks)
- We've managed to reconstruct the MC XS with a good precision with respect to the MC true XS (still room for improvement) starting from the output provided by the tracking algorithm:
  - First complete quantitative check of the tracking algorithm output **(check not yet done for magnetic field with the full setup)**.
  - Nice team effort of many members of the analysis crew for the analysis of the global tracking output to study and identify the **needed selection criteria which had allowed a MC closure test** at the actual state (see Giacomo U's talk)
  - We're starting to understand better our detector / the full reconstruction and its limits. Important tool for all the analysis and a "meter" to take decisions for future data taking (for example in terms of statistics)

- **Work extended and adapted by RobZ for CNAO2023 campaign with full setup→ MC closure test for Z production (mass still missing) and global tracking performances**
- I would like to see the effect of the same set of selection for alpha clustering analysis with the electronic setup

Important implications

- **Rejection of background** (out of target, combinatorial and cross feed) **can be managed with appropriate cuts / selections:**
  - ➢ no need to implement anymore background subtraction technique from “no target” data (?)
  - ➢ If verified also for the full setup (magnet included), this will allow us to save time during data collection
- Still room for detector reconstruction improvement (see VTX cluster size and MSD eta function useful for ghost removal and ZID algorithm). But **now we can estimate the impact of their implementation in the XS** (→ the most important removal of combinatorial background) and evaluate it in terms of manpower / time for publication
- **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 to show to the FOOT referees we’re able to do it (this is something they’ve asked us to do)

Data analysis: what is still missing?

- **To apply the full reconstruction to the data we still need to study many experimental effects and tuning the MC accordingly:**
  - ➢ efficiency / thresholds of the trackers (considered protons excluded for the moment)
  - ➢ 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)
  - ➢ Tuning of the experimental resolutions in MC for every measured quantity not completed yet
  - ➢ Effects of 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 seen at CNAO 2023)

Titles for your next master student thesis

- Study of pile up in the high beam rate data runs acquired at CNAO 2023 + tuning in MC to study strategy and efficiency in pile-up rejection
- MSD eta function / charge equalization and implementation of ZID and ghost removal
- MSD and VTX efficiency / threshold study in data and tuning in MC
- To perform mass identification with CALO we need a calibration along the full energy range of interest: it can be done using Ekin information from Tof measured by TW-SC for each Z for TW points matched to the CALO
- To perform measurements of protons with the electronic setup we need to study the thresholds in TW: it could be done using physics data using energy information from the calorimeter once calibrated
- If we're able to reject the out of target fragmentation and so also to reject the pre-target fragmentation → possibility to explore pro and cons of greater thickness for SC (ToF improvement / mass separation wrt Eloss / loss of statistics)


come fai..SBAI

Analysis summary and manpower distribution

Campaign	MC analysis: Closure test (Efficiency, Purity, unfolding, background rejection)	Systematics	Raw Data analysis	Calo matching	Physics
GSI 2021	No track: Riccardo Tracking: Giacomo U.	No track: Riccardo	(*)	No calo	O+C, O+C_2H_4 , O+H @ 400 MeV/u H+O inverse XS ?
GSI 2021	-	-	(*)	No calo	O+C, O+C_2H_4 , O+H @ 200 MeV/u H+O inverse XS
HIT 2022	-	-	(*)	Mass spectra: Alessandro, Francesca, Tino	He+C @ 100, 140, 200, 220 MeV/u
CNAO 2022			(*)	-	C+C @ 200 MeV/u alpha clustering?
CNAO2023 (+ Full setup MC)	Tracking: RobZ alpha clustering: Milano	-	(*)	-	C+C, C_2H_4 , C+H @ 200 MeV/u H+C (inverse XS) alpha clustering

(*) Some data analysis always performed in the proximity of the data taking (Pile-up, efficiency / thresholds, Fragmentation trigger, resolutions in data/MC analysis for different detectors, …)

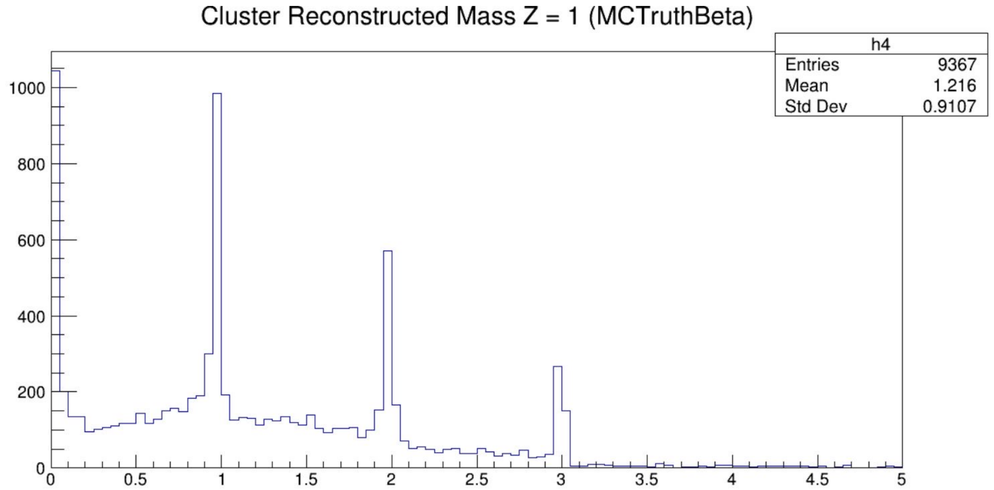
Conclusions 1: FOOT priorities in XS analysis

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)

HIT2022 status

- Possibility to identify p, d, t and ^{3}He in ^{4}He+C interactions
- First attempt to identify them with ToF and Calo in MC, using true ToF (**Alessandro, Francesca and Tino** work)
- Calibrations of CALO and TW done

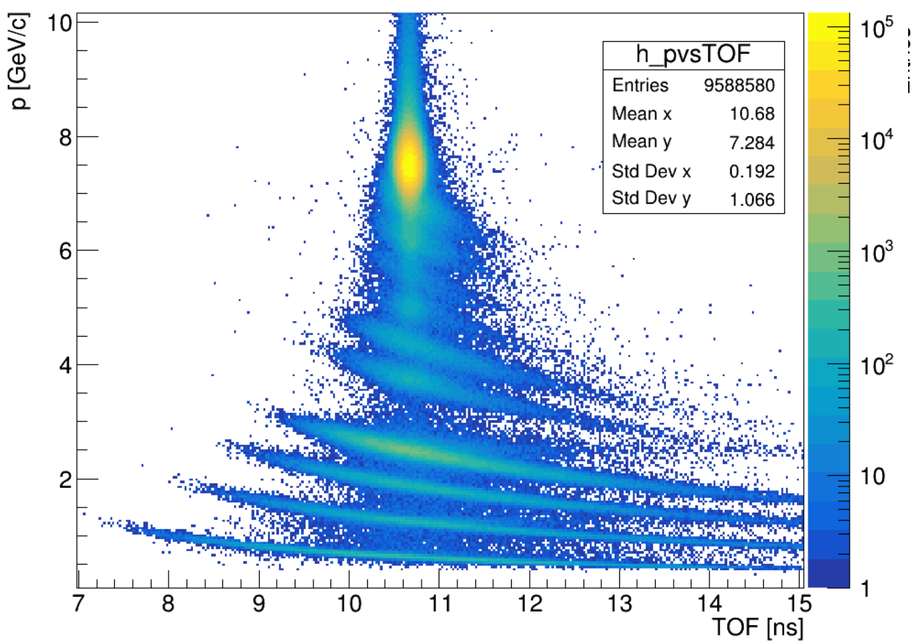


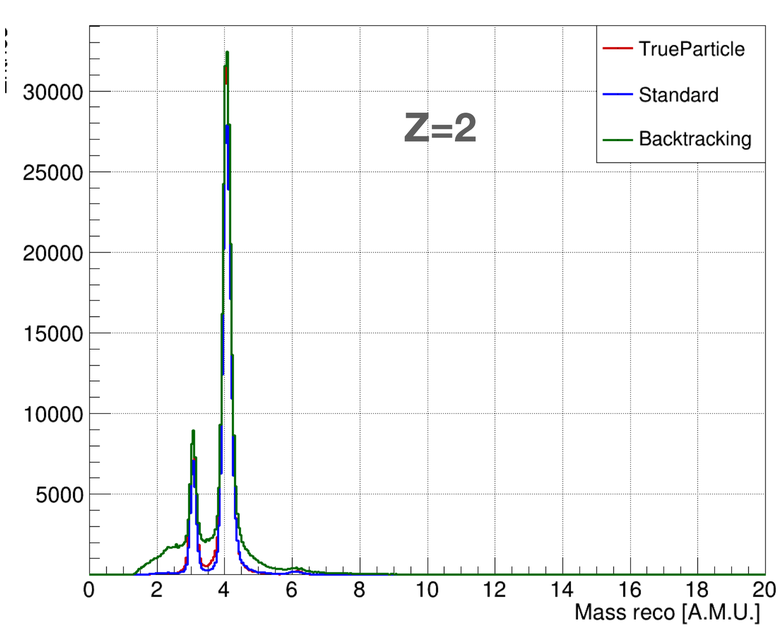
What is missing?

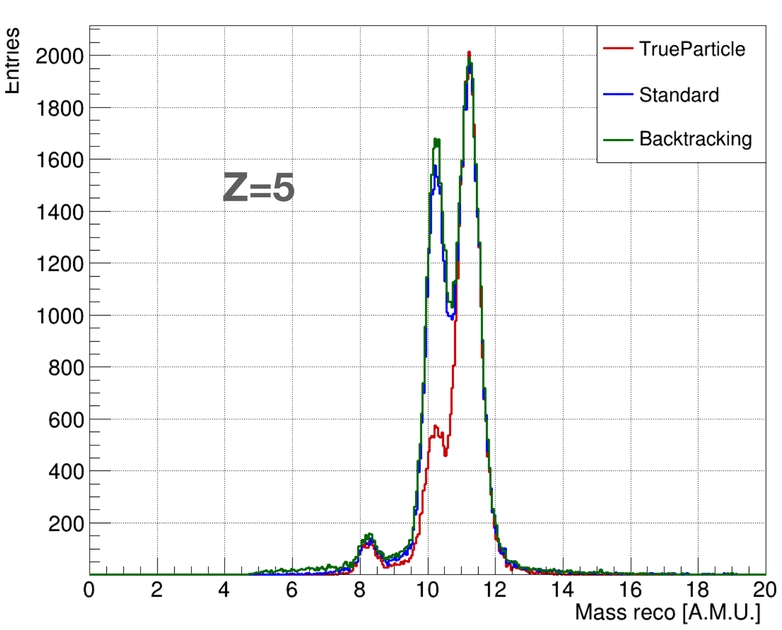
- **Need to tune the tracking algorithm for this campaign (No VT) using backtracking developed by RobZ and verify it with a MC closure test for XS. Vertexing in this case not included yet**→ useful also for GSI 2021 O @ 200MeV/u (no VTX included)
- Data analysis, study of efficiency of MSD to protons and tune the MC accordingly:
- Implement of TW calibration / resolution in shoe
- CALO reconstruction performances to be verified
- Have pile up, high rate effects, Tof worsening some impact in this setup?

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