Assessing the TIARA detector performances with carbon beams at CNAO facility

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October 9th 2024, GdR Mi2B

Context of carbon ion therapy at CNAO

PGTI
PROMPT GAMMA TIME IMAGING

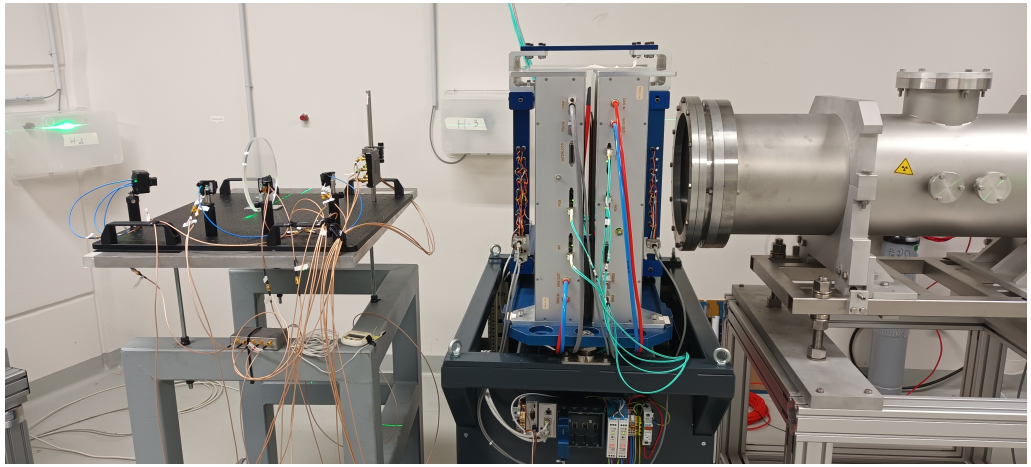
Accelerator characteristics

Carbon/proton synchrotron located at CNAO in Pavia, Italy

Beam energy range for carbon ions : **120 MeV/u – 400 MeV/u**

Beam size FWHM : **4 mm – 8 mm**

CNAO
The National Center for Oncological Hadrontherapy



Context of carbon ion therapy at CNAO

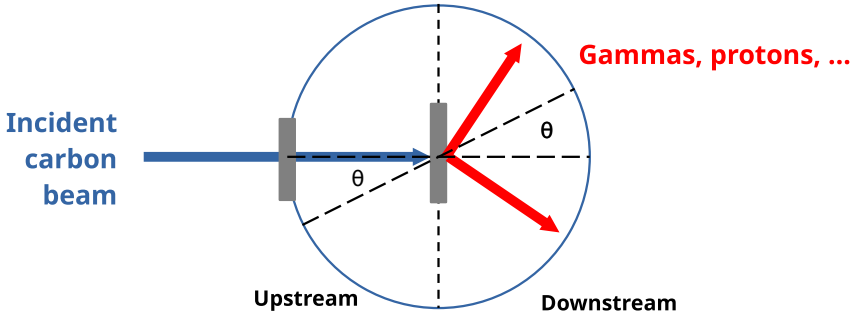
PGTI
PROMPT GAMMA TIME IMAGING

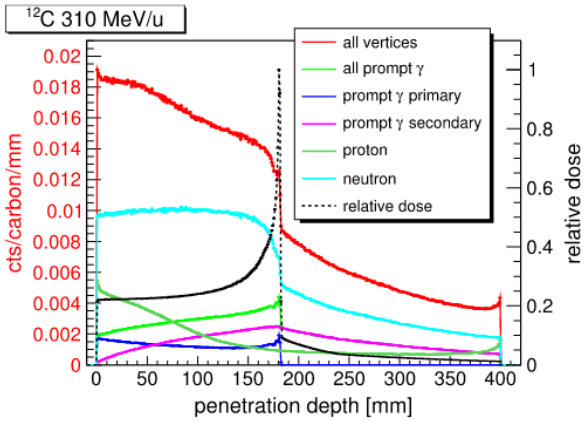
Carbon ion particularities

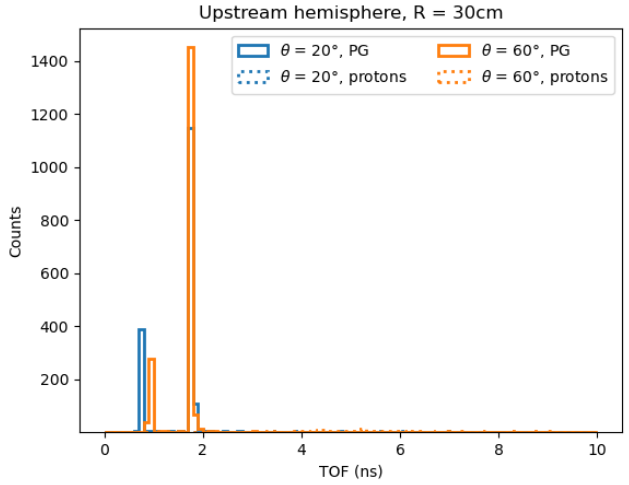
High biological effectiveness (higher LET than protons)

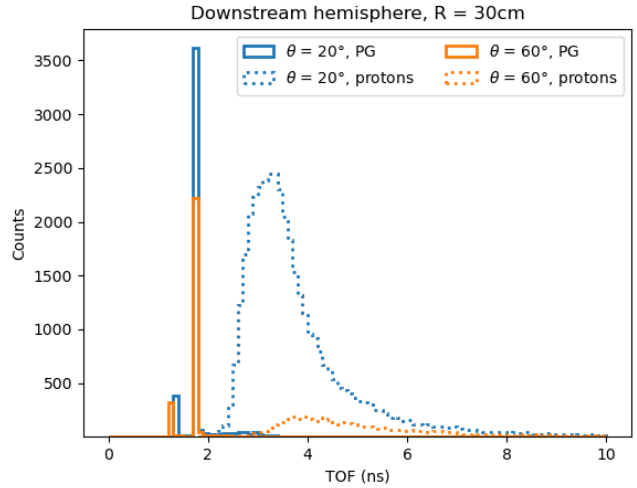
Higher Prompt Gamma production rate **per ion**

Fragmentation tail of secondary particles (mostly protons)









J. Krimmer et al. Prompt-gamma monitoring in hadrontherapy: A review. Nucl. Instrum. Methods Phys. Res. A, 2018, 878, pp.58-73. 10.1016/j.nima.2017.07.063

Context of carbon ion therapy at CNAO

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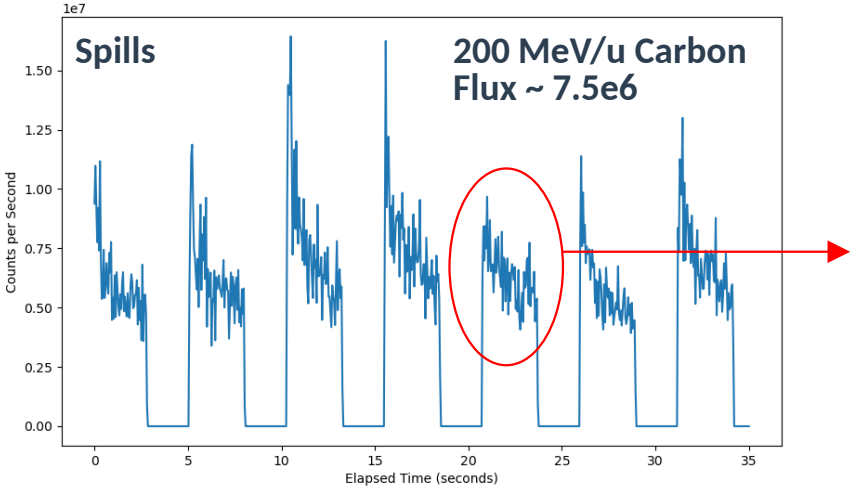
Time structure of synchrotron beam

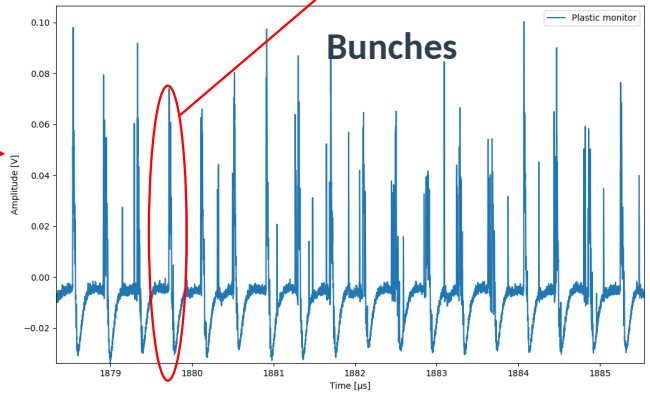
Spills : ~ 2 s ON, ~ 1 s OFF

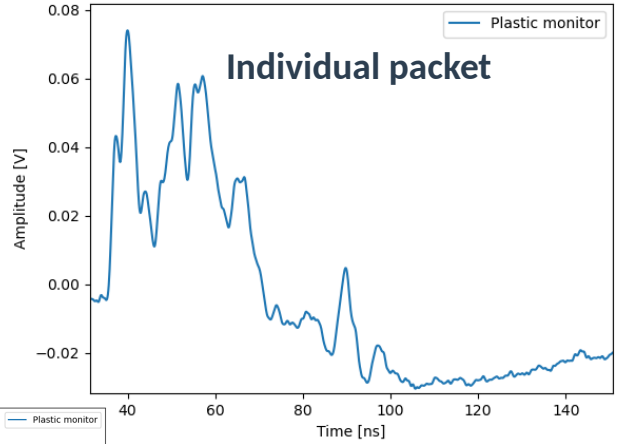
Micro-structure due to synchrotron period

Chosen fluxes slightly lower than clinical, but not Single Particle Regime



Beam structure as seen by CNAO instrumentation during our irradiations, July 2024
Data courtesy of Marco Pullia





Beam on small time scale as seen by our plastic monitor during irradiation, July 2024

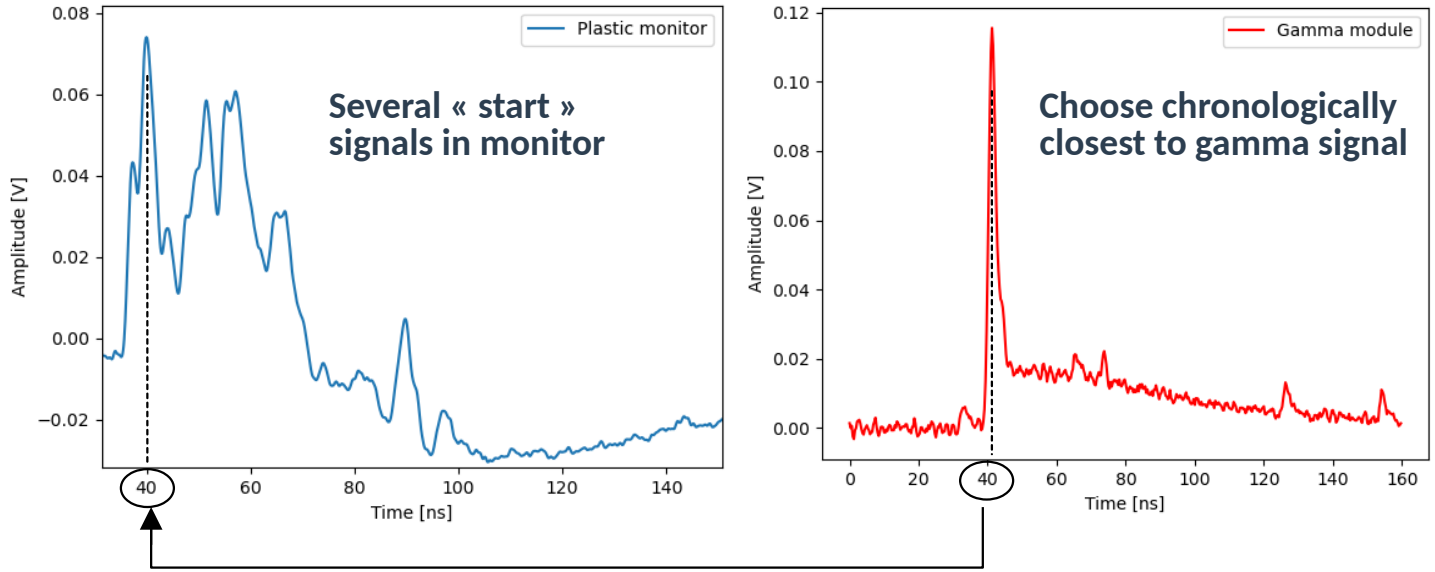
Context of carbon ion therapy at CNAO

PGTI
PROMPT GAMMA TIME IMAGING

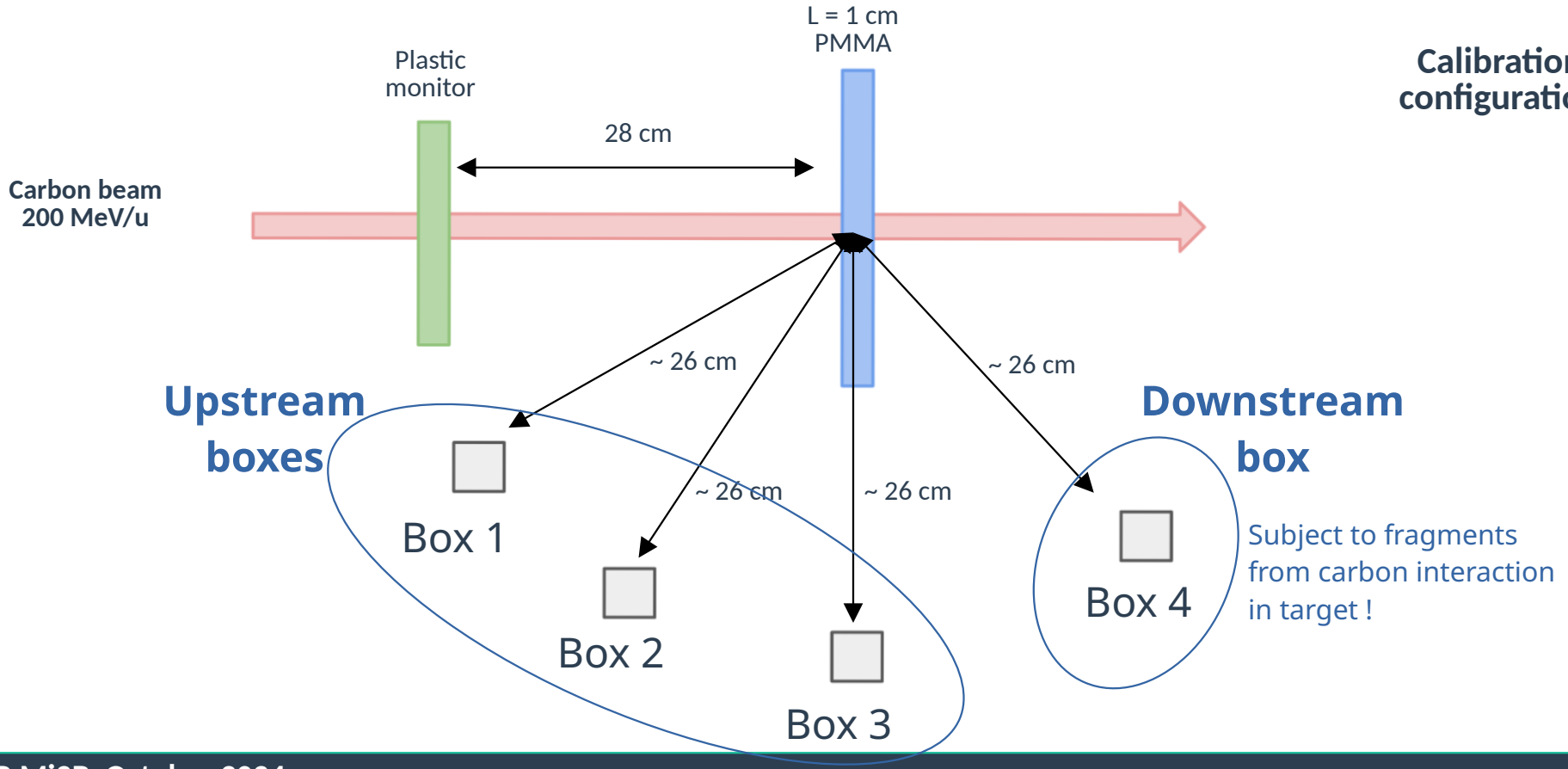
Choice of start pulse in monitor signals

Chosen carbon ion flux results in multiple signals in short time window

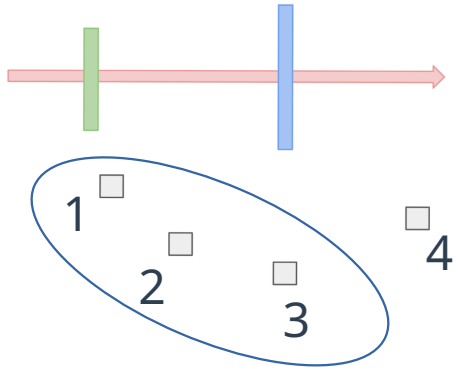
Allows minimisation of false coincidences



Calibration : Thin target configuration

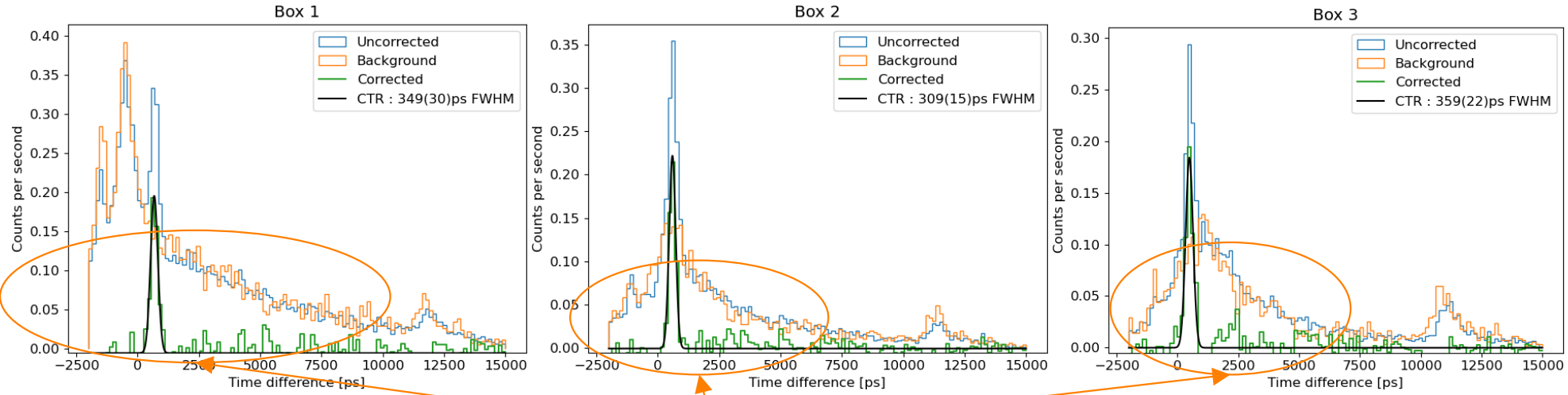


Calibration : Upstream boxes, Time of Flight



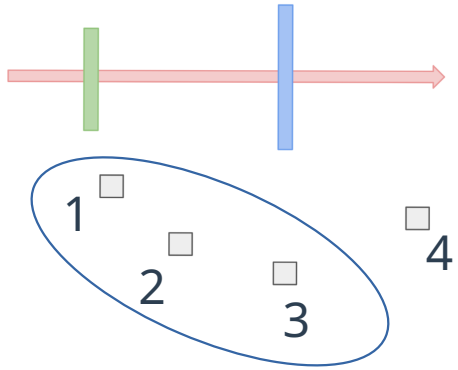
Time of Flight measurements – upstream boxes

200 MeV/u @ 7.5 10^6 carbons/s



Piedestal induced by start signal choice

Calibration : Upstream boxes, Time of Flight



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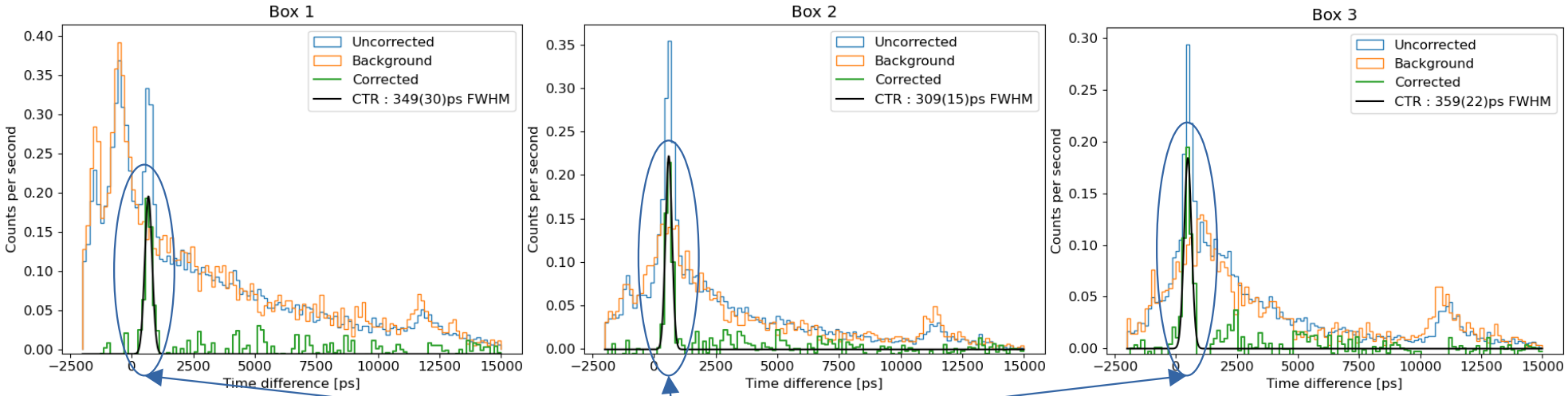
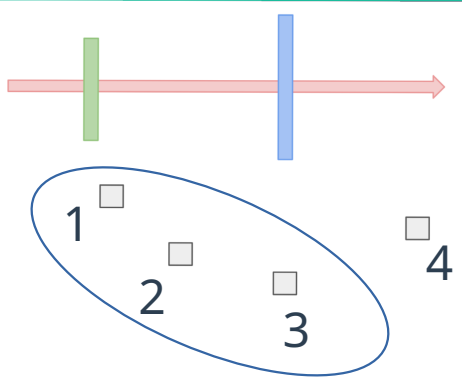


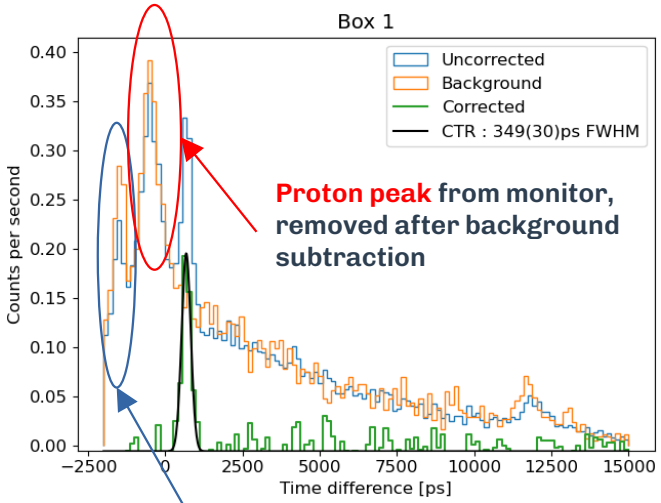
Prompt gamma peak from target,
isolated after background subtraction

Calibration : Upstream boxes, Time of Flight



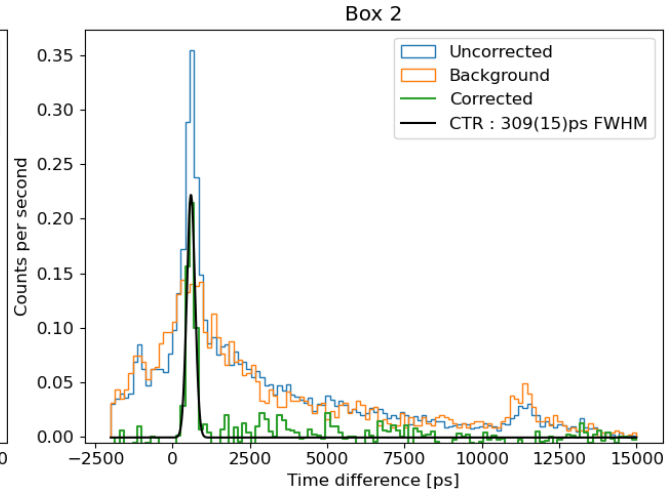
Time of Flight measurements – upstream boxes

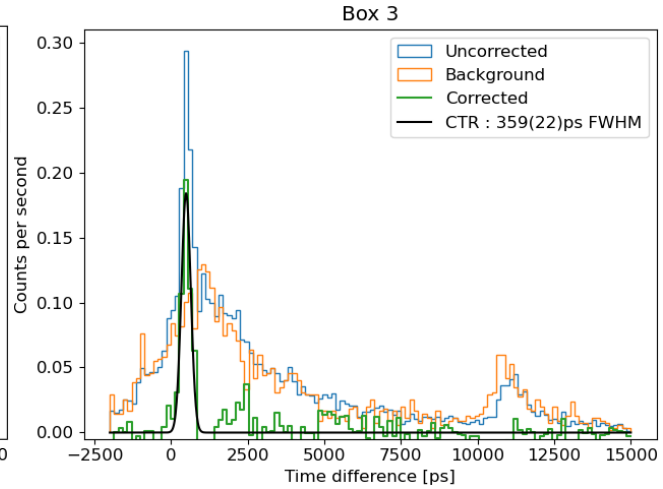
200 MeV/u @ 7.5 10^6 carbons/s



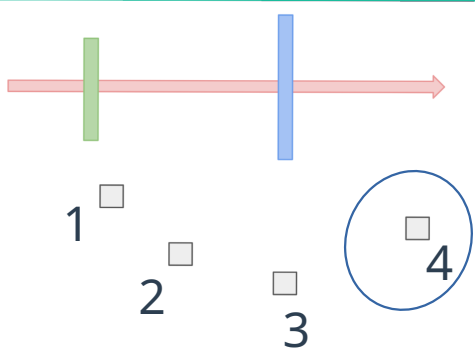
Proton peak from monitor, removed after background subtraction

Prompt gamma peak from monitor, removed after background subtraction



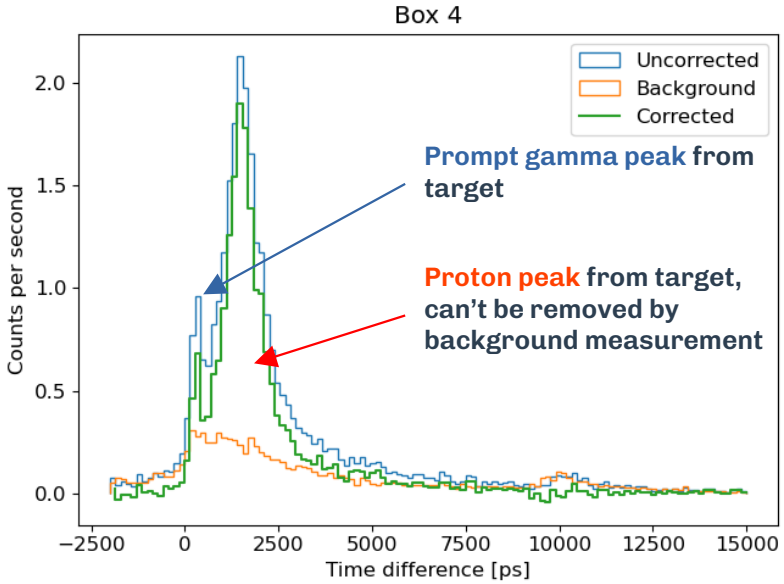


Calibration : Downstream box, Time of Flight

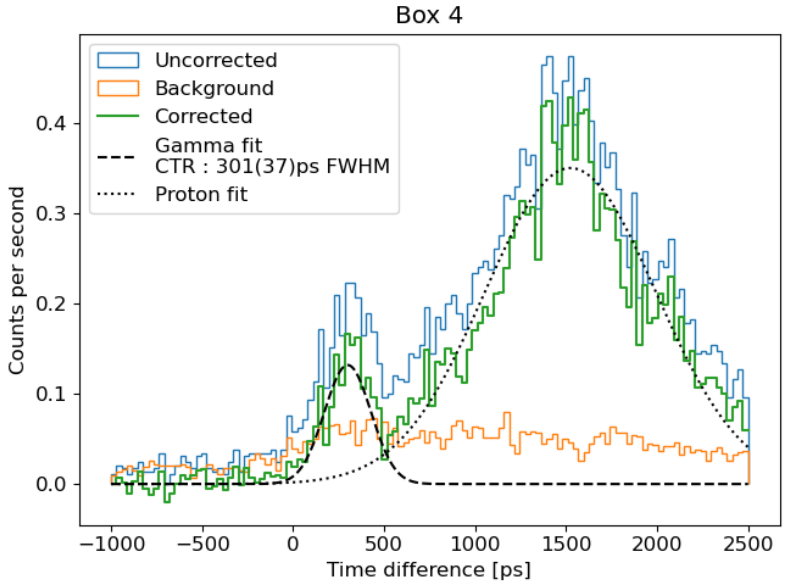


Time of Flight measurements – downstream box

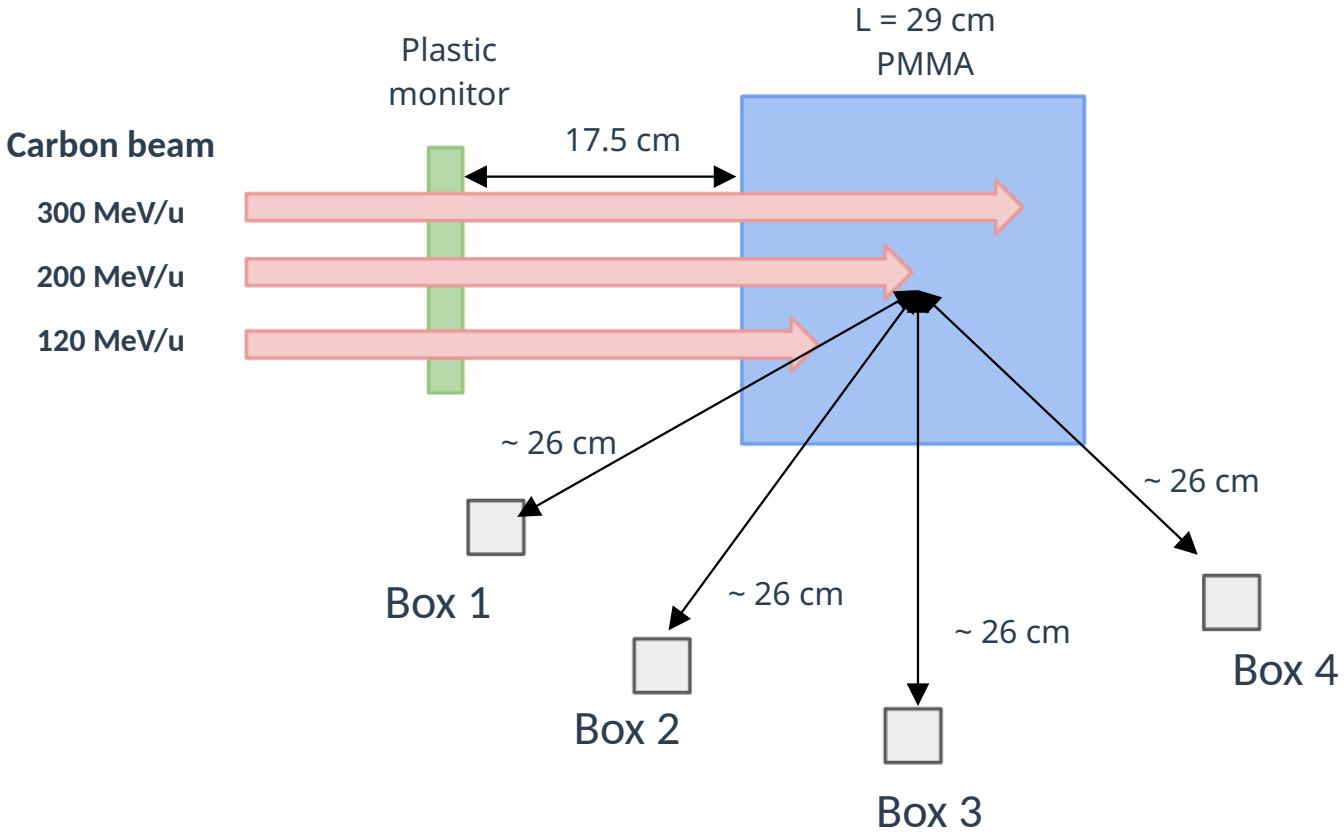
200 MeV/u @ 7.5 10^6 carbons/s



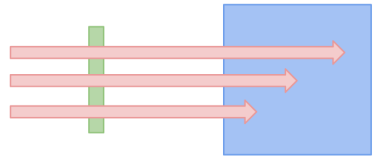
Subtract proton contamination by fitting :
Good enough for calibration

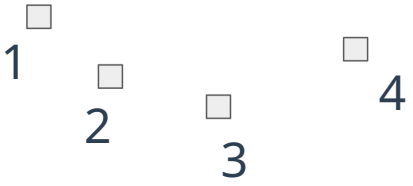


PMMA phantom range shifts, configuration



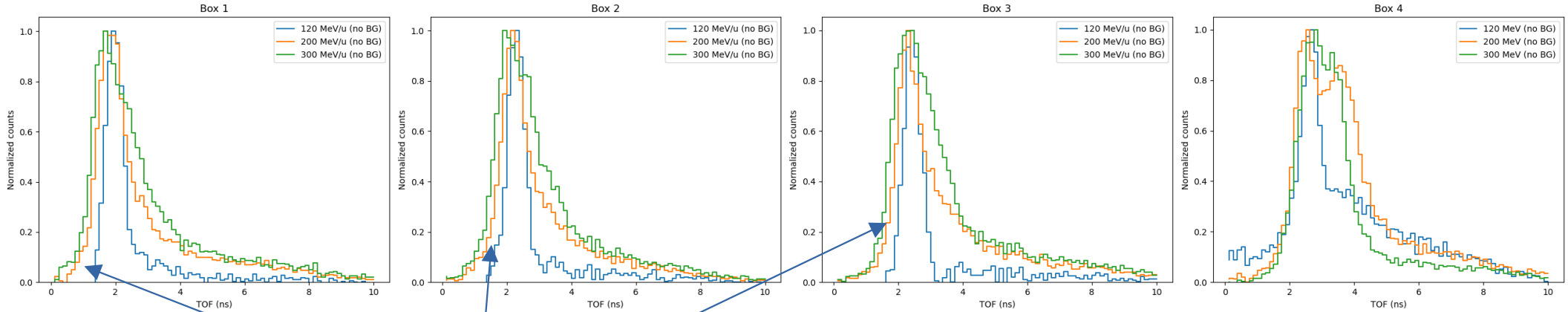
PMMA phantom range shifts, all boxes





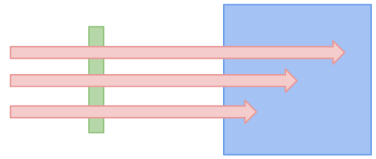
TIARA sensitivity to range shifts in thick PMMA target

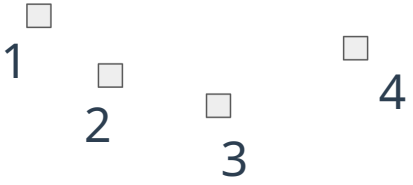
120 MeV/u (~32 mm) @ 6 10^6 carbons/s
200 MeV/u (~84 mm) @ 7.5 10^6 carbons/s
300 MeV/u (~168 mm) @ 8 10^6 carbons/s



Time difference between monitor and target entrance

PMMA phantom range shifts, all boxes





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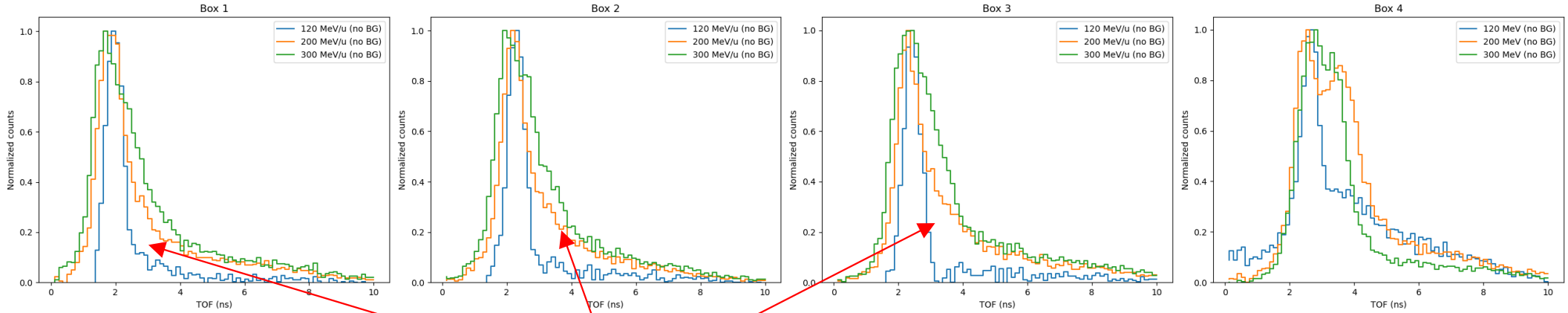
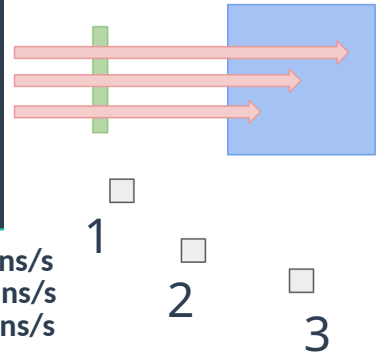


Prompt Gammas generated in fragmentation tail

PMMA phantom range shifts, all boxes



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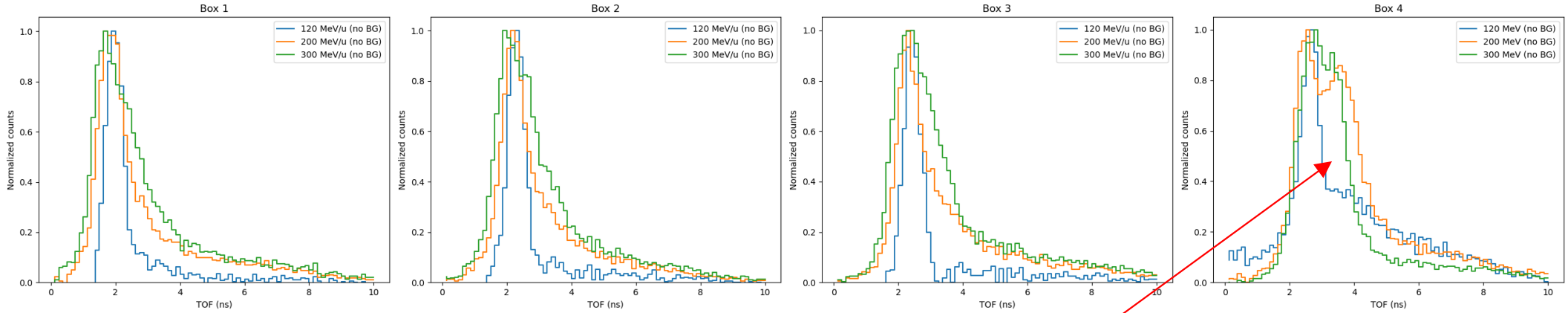
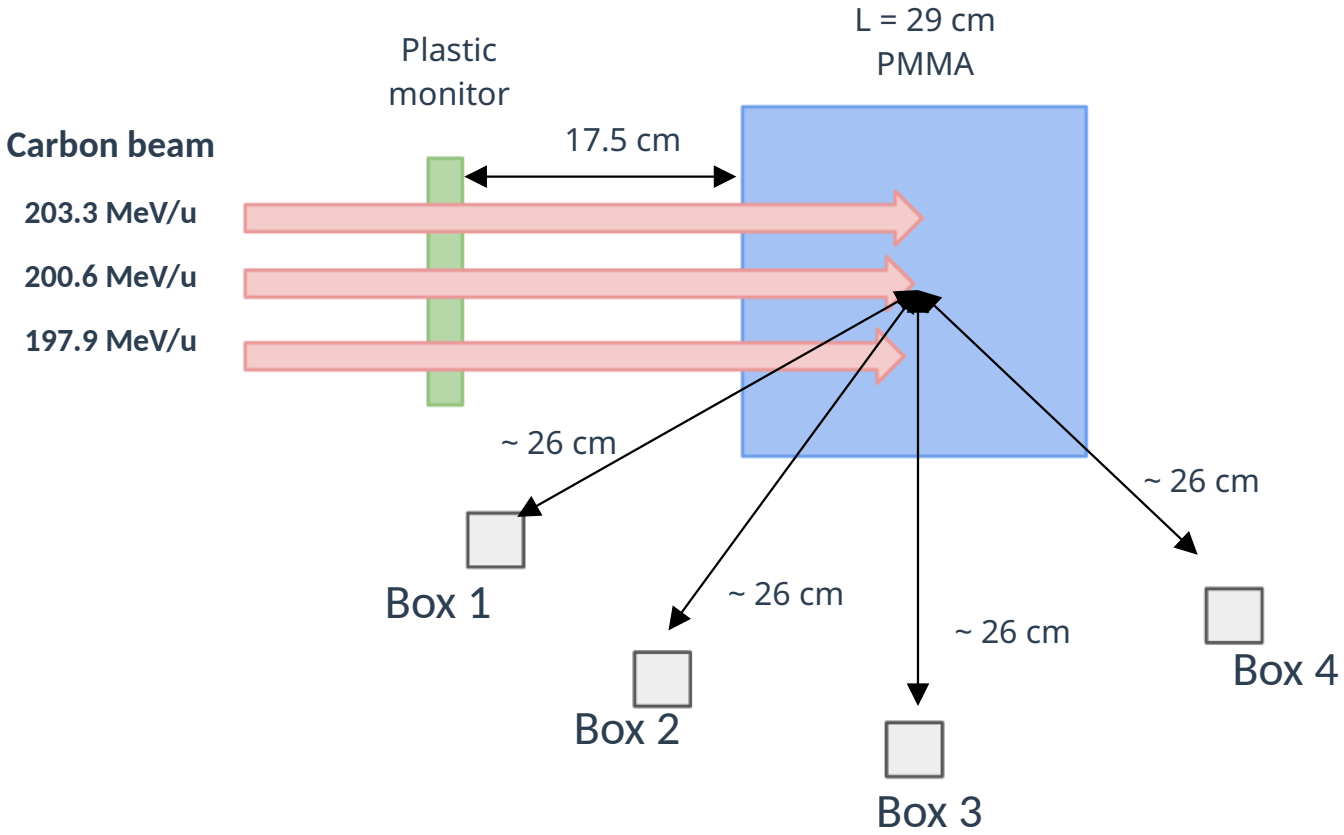
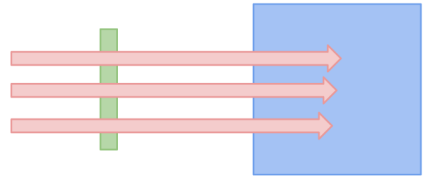


Protons escaping thick target +
Prompt Gammas from
fragmentation tail

PMMA phantom millimetric range shifts, configuration



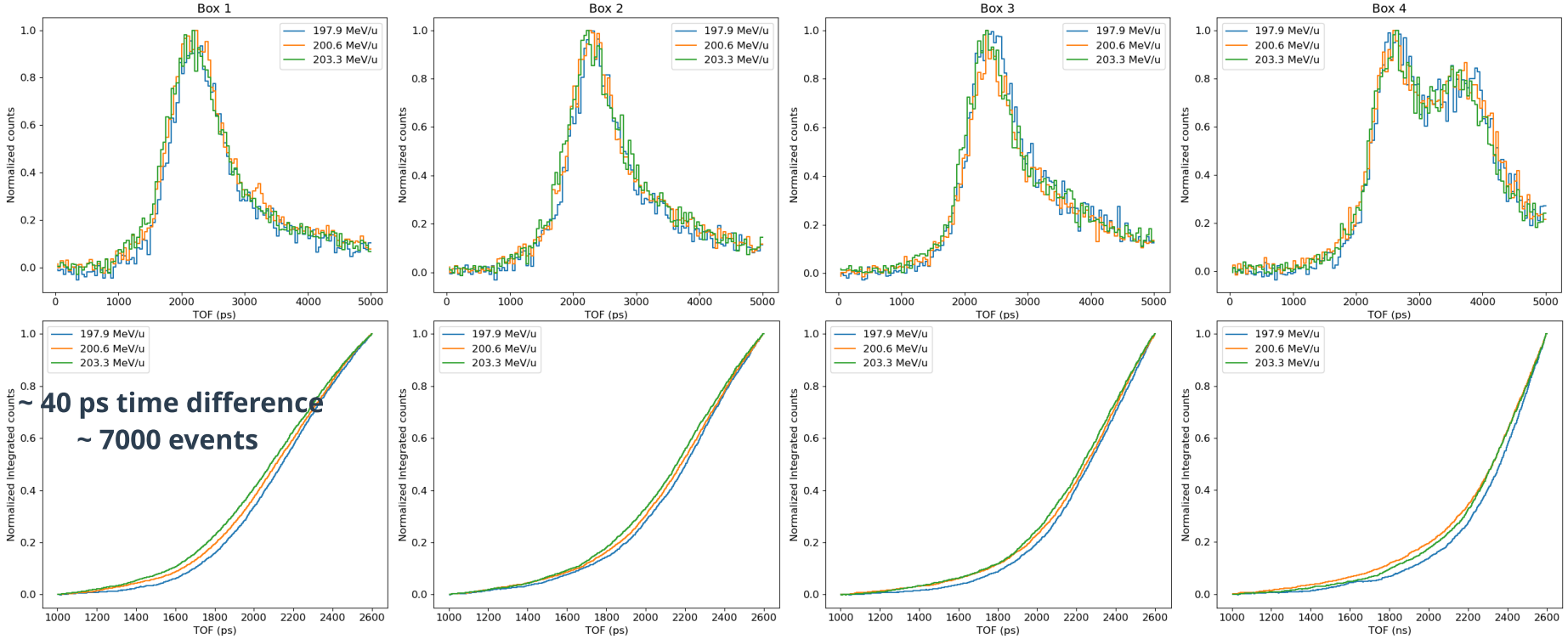
PMMA phantom millimetric range shifts, all boxes



1 2 3 4

Time of Flight measurements

197.9 MeV/u (82 mm) @ 6 10^6 carbons/s
200.6 MeV/u (84 mm) @ 6 10^6 carbons/s
203.3 MeV/u (86 mm) @ 6 10^6 carbons/s



Conclusion

PGTI
PROMPT GAMMA TIME IMAGING

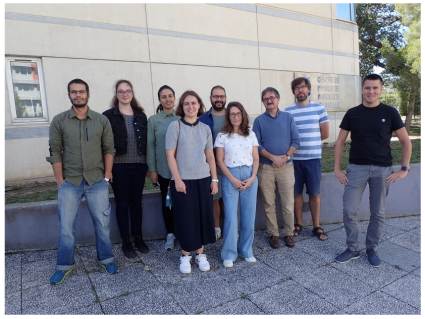
Compatiblity of the TIARA system with carbon ions from synchrotron beams

Ongoing analysis to calculate range sensitivity

Correct placement of boxes is crucial to avoid secondary particles with carbon beams

Acknowledgments and credits

The **TIARA Collaboration**



LPSC: S. Marcatili, A. André, ML. Gallin-Martel, L Gallin-Martel, C. Hoarau, P. Kavrigin, J-F Muraz, M. Pinson

CPPM: Y. Boursier, A. Cherni, M. Dupont, A. Garnier, C. Morel

CAL: D. Maneval, J. Hérault, J-P Hofverberg

Funded projects

IRS – Initiative de Recherche Stratégiques (project ANR-15-IDEX-02)

PCSI TIARA (Convention n°20CP118-00)

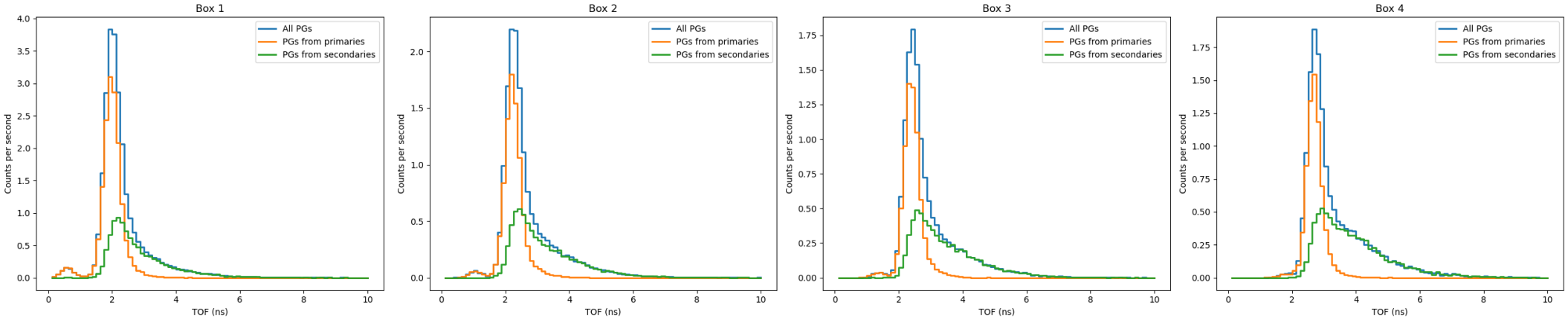
ERC Starting Grant (project 101040381)

This work was partially supported by the **European Union (ERC project PGTI, grant number 101040381)**. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or the European Research Council Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

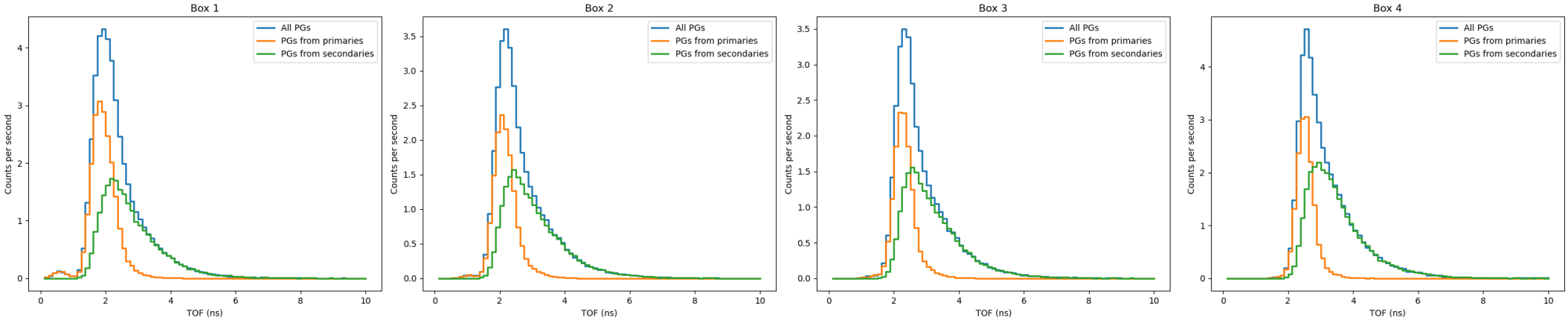
Special thanks to:

- CAL/IN2P3 COMEX for the allocated beam time
- HITRIplus project for beam time at CNAO and related travel expenses
- Marco Pullia (CNAO) and his team for the nice reception
- Labex PRIMES for funding beam time at CAL and two M2 internships

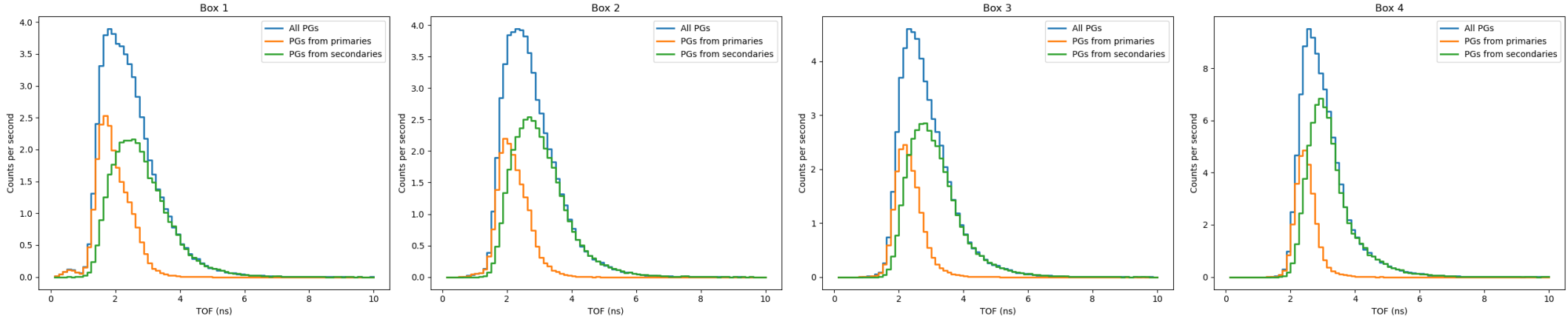
Carbon 120 MeV/u



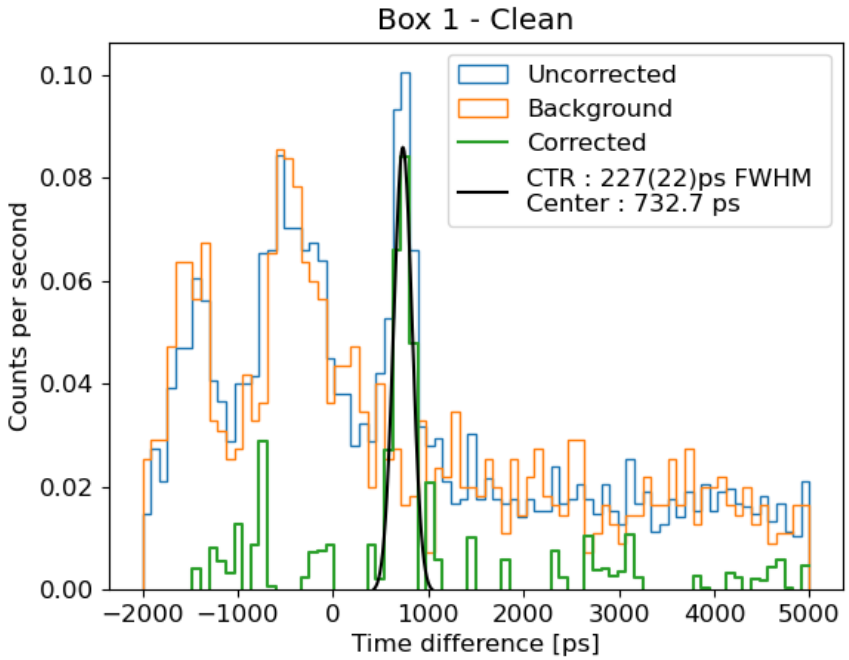
Carbon 200 MeV/u



Carbon 300 MeV/u



CTR calculation after isolating single carbon peaks in monitor



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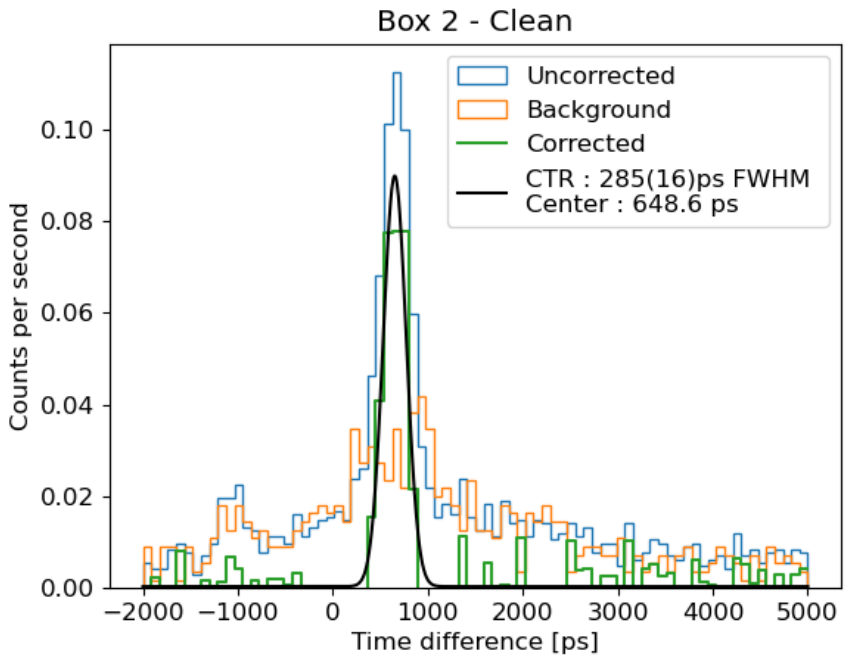

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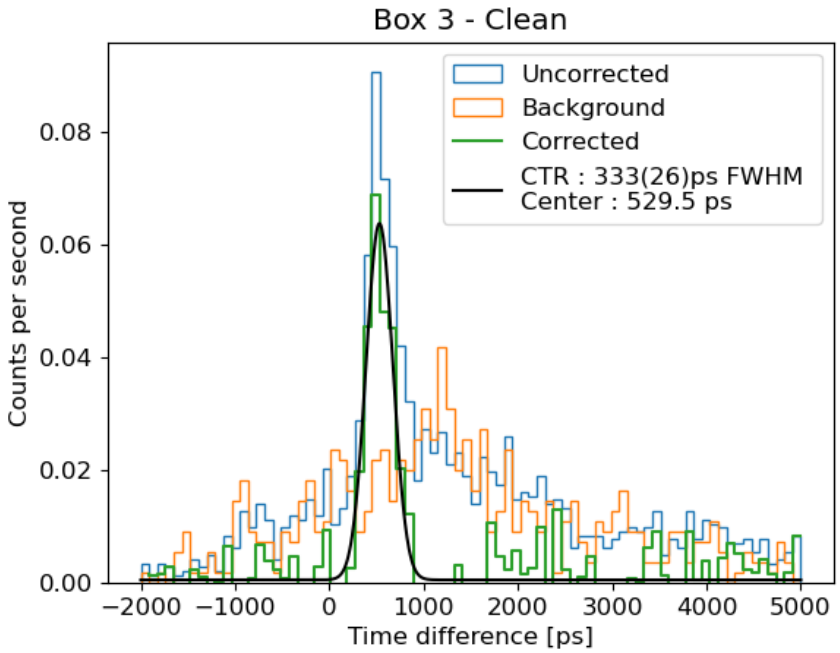

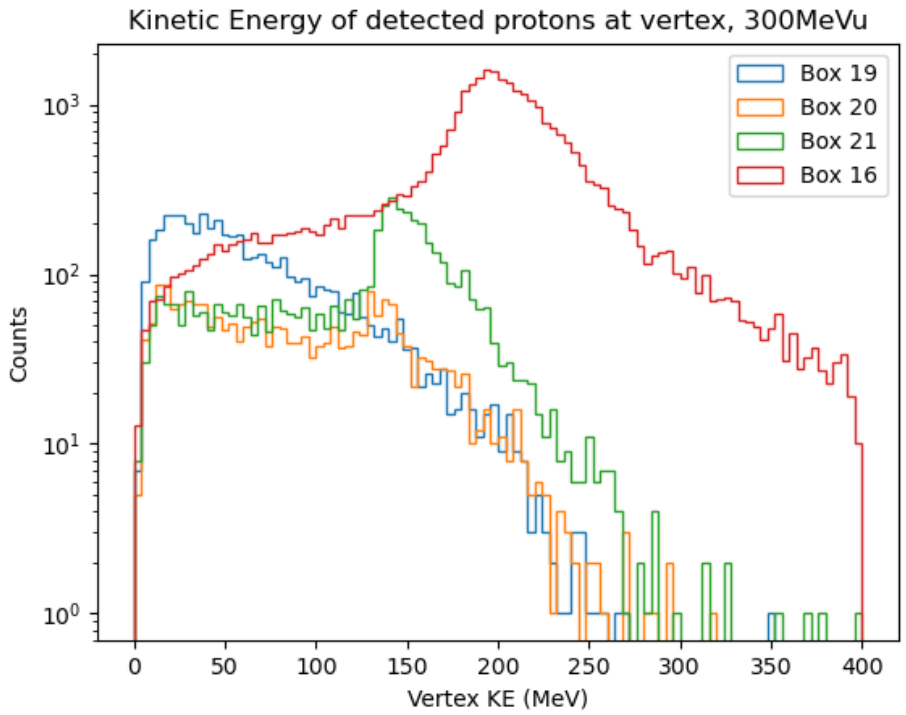
Kinetic Energy of detected protons at vertex, 300MeVu
Box 19
Box 20
Box 21
Box 16
Counts
10^3
10^2
10^1
10^0
0
50
100
150
200
250
300
350
400
Vertex KE (MeV)