



FOOT

FragmentatiOn Of Target

CSN3: 2018-20

Responsabile nazionale: V. Patera (Roma 1)

Responsabile Locale a Milano: G. Battistoni

Programma Scientifico della sigla: misura delle sezione d'urto di frammentazione del target e del proiettile per applicazioni in adroterapia e radioprotezione

Attività di ricerca e sviluppo della sigla: realizzazione di un esperimento "table top" in due modalità: emulsioni nucleari e apparato con spettrometro magnetico, misura di ToF e calorimetro per identificazione di Z, A dei frammenti prodotti nelle interazioni di C,He,O con C,H,O nel range di energia 200-800 MeV/u

Laboratori per misure della sigla: GSI, CNAO, Heidelberg

Sigla Milano

Ricercatori:	2
Tecnologi:	1
Ass-Dott:	2
FTE:	2.8 (da verificare)

Sezioni INFN coinvolte: BO, LNF, MI, NA, Pi, PG, RM1, RM2, TIFPA, TO
International partners: GSI, IPHC Strasbourg, Nagoya Univ., Aachen Univ.
~100 partecipanti (60% staff)

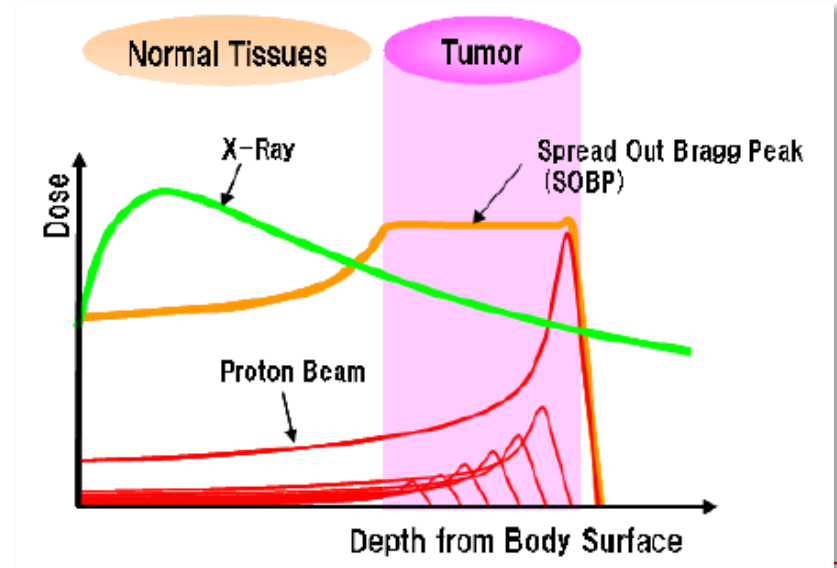
FOOT goals

- Radioprotection in Space (RPS)



- p, He, C, O beams (the most common in space)
- Radioprotection energies (around 800 MeV/u)
- $d\sigma/dE$ and $d\sigma/d\Omega$ with 5% precision of the fragment production to optimize the spacecraft shielding (long term missions)

Particle therapy (PT)



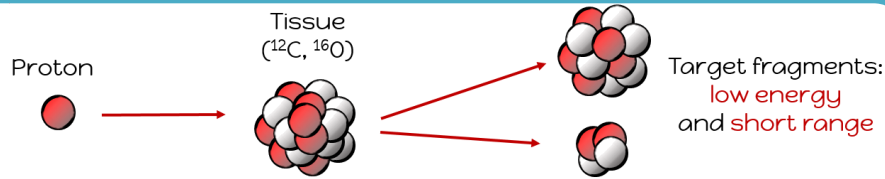
- Target fragmentation produced by p beams at about 200 MeV
- Projectile fragmentation produced by He, C, O beams at 200-400 MeV/u
- $d\sigma/dE$ and $d\sigma/d\Omega$ with 5% precision of the fragment production to improve treatment quality

*In connessione con la Call CSN5 MoVE-IT
(Modeling and Verification for Ion beam Treatment planning)*

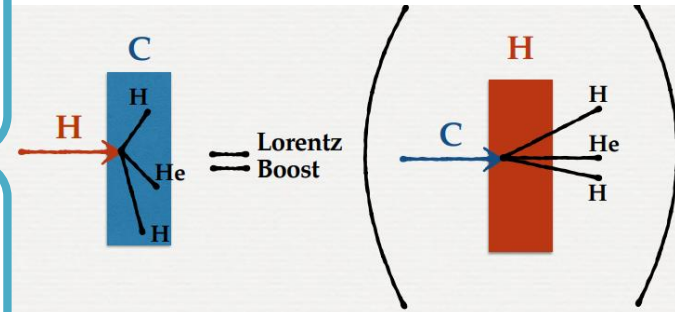
MoVe IT

Strategies for target fragmentation

DIRECT KINEMATICS

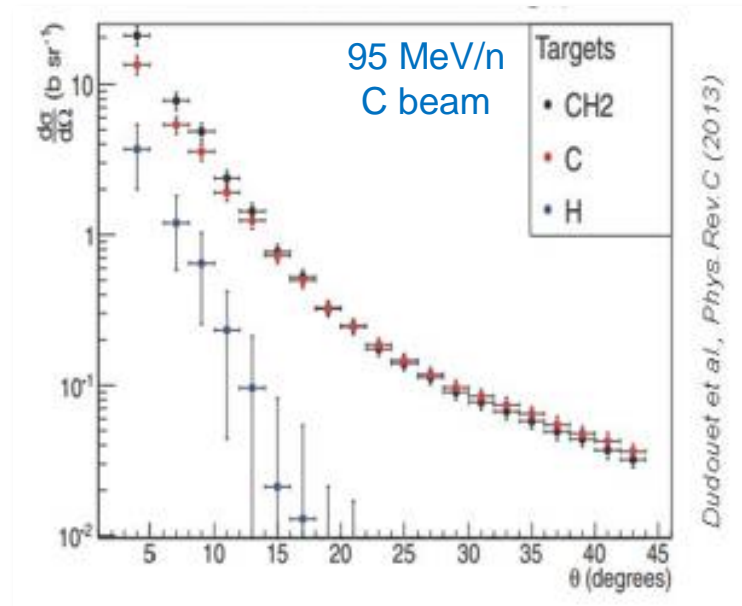
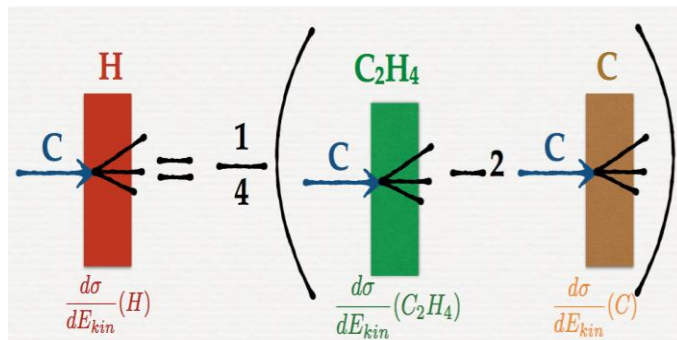


INVERSE KINEMATICS



Hydrogen gas target:

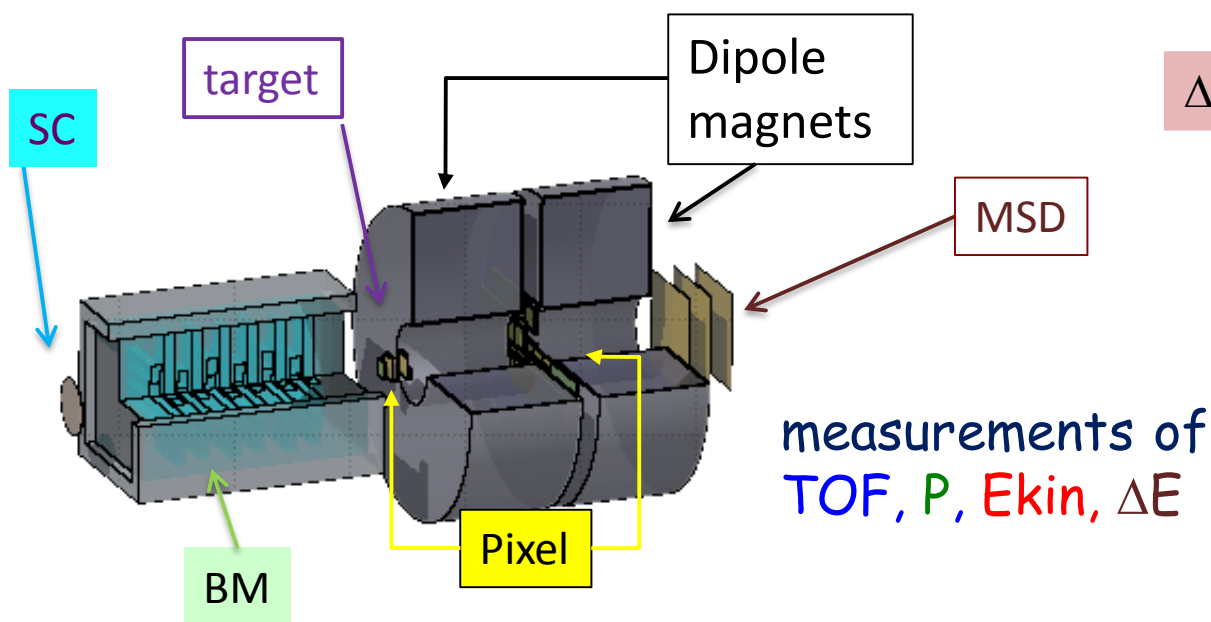
- ⊗ Low interaction probability
- ⊗ Not allowed in therapy facilities



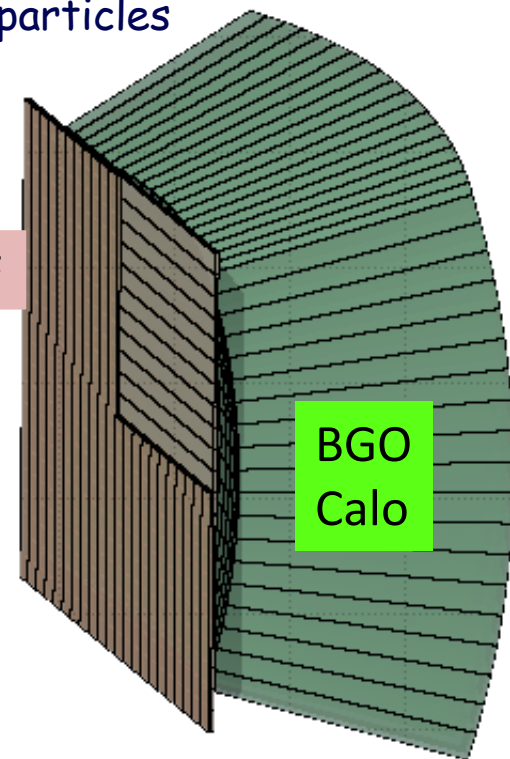
setup for "heavy" ($Z \geq 3$) particles

Electronic Detector

$\Theta < 10^\circ$



$\Delta E/TOF$



Length < 2.5 meters

- ✓ Start Counter = thin plastic scintillator
- ✓ Beam Monitor = drift chamber (Milano)
- ✓ Vertex detector = silicon pixel detector
- ✓ Inner Tracker = silicon pixel detector
- ✓ Large tracker = silicon micro strip detector
- ✓ $\Delta E/TOF$ Detector = plastic scintillator
- ✓ Calorimeter = BGO crystal calorimeter

performances
@200MeV/u:

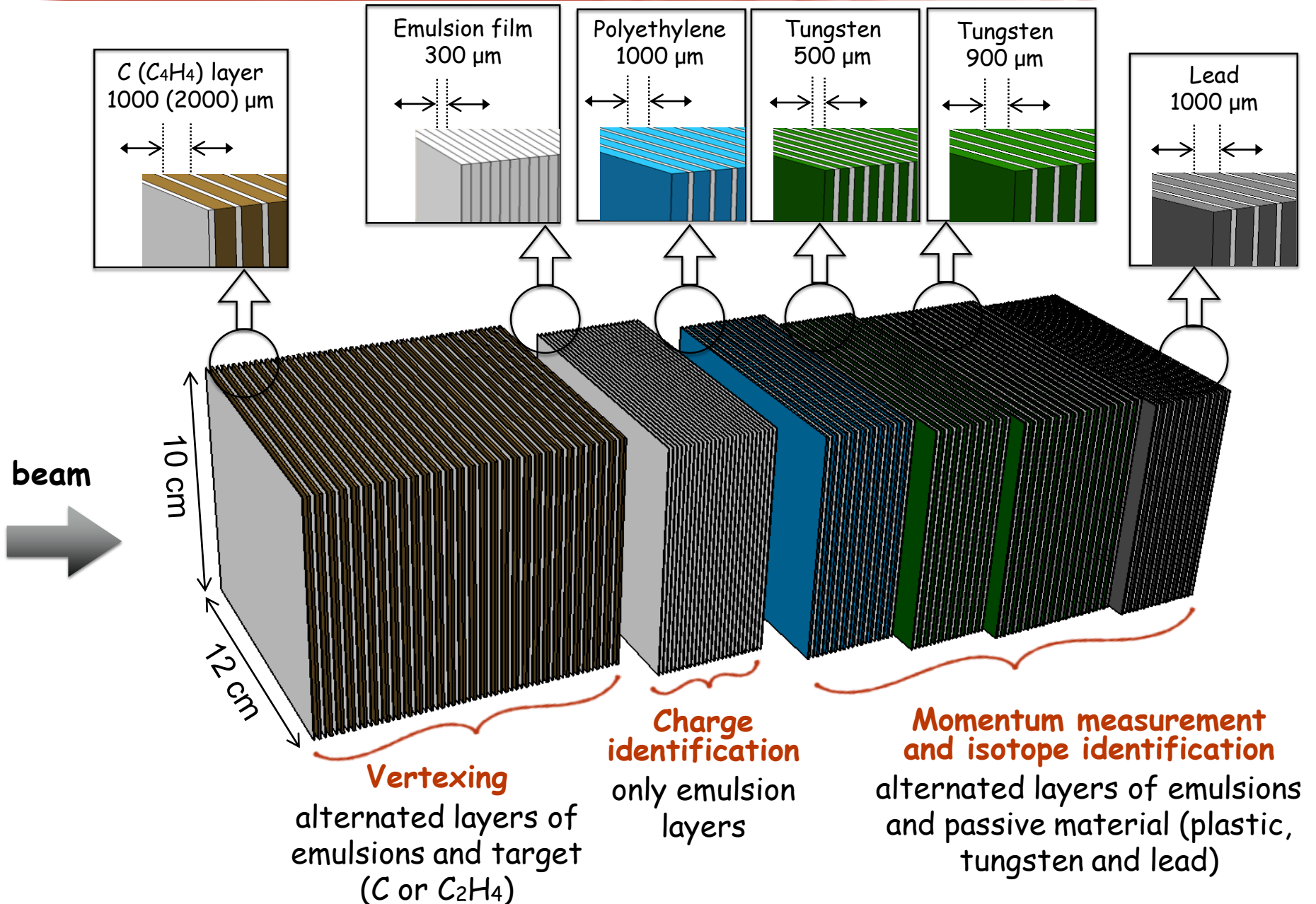
$$\int_p/p \sim 4\%$$

$$\int_{TOF} \sim 70 \text{ ps}$$

$$\int_{E_{kin}}/E_{kin} \sim 2\%$$

EMULSION SPECTROMETER DESIGN

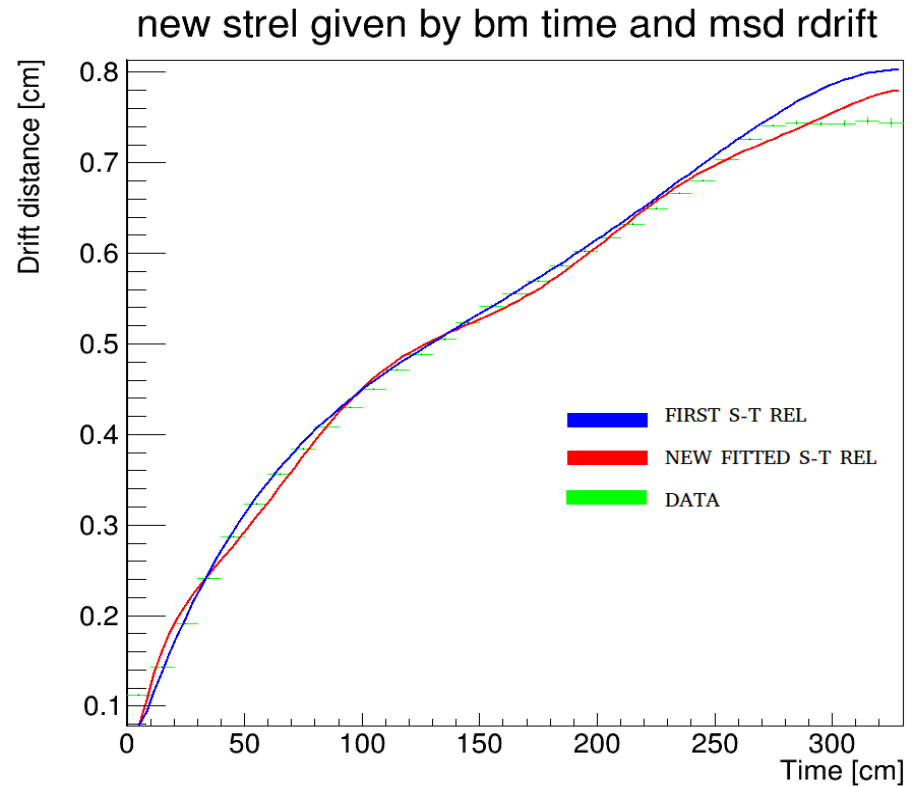
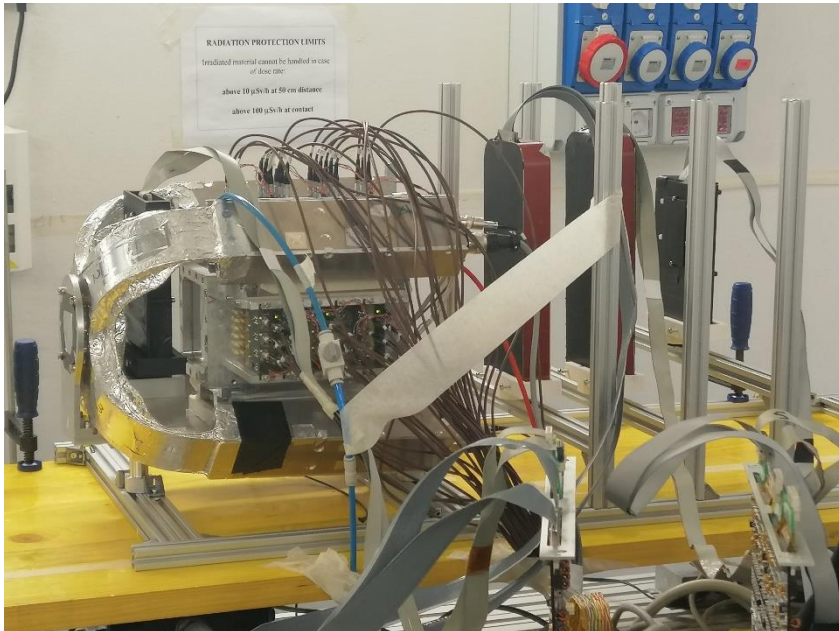
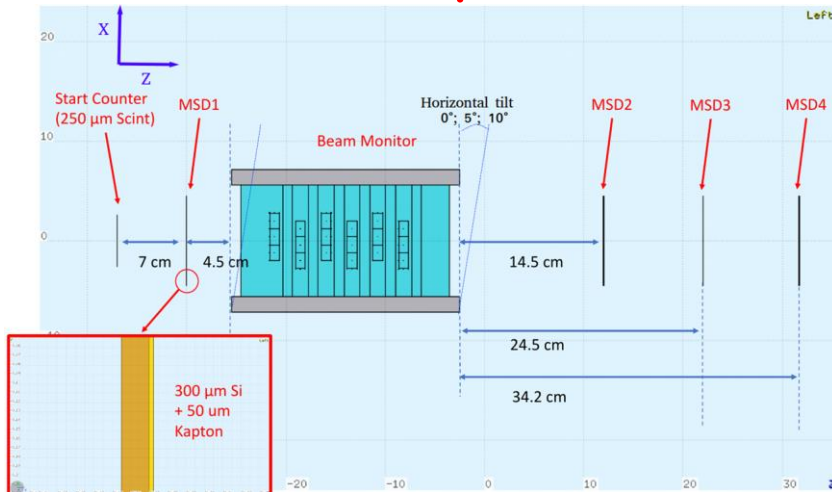
setup for "light" ($Z \leq 3$) particles up to large angles



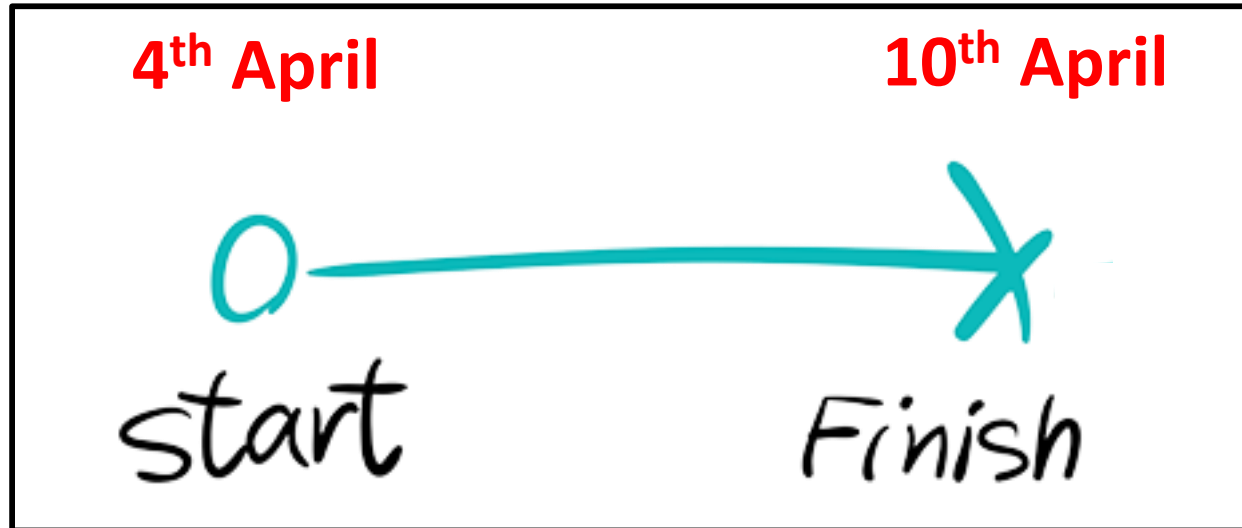
Breve sintesi attività svolta a Milano nel 2018-2019

- 1) Operazione, test e calibrazione della Drift Chamber usata come Beam Monitor (in collab. con TIFPA):
 - I. Realizzazione sistema di distribuzione gas
 - II. Test beam con protoni a Trento (Ottobre+Dicembre 2018, Marzo 2019, in collab. con TIFPA e Pg)
 - III. Software di ricostruzione Beam Monitor
- 2) Simulazione MC dell'esperimento
- 3) Coord. Studio delle Performances del detector
- 4) Partecipazione allo sviluppo software di ricostruzione generale
- 5) Partecipazione a presa dati al GSI (Aprile 2019)
- 6) Organizzazione Meeting di Collaborazione (Giugno 2019)

Test Beam @Trento: BM space-time rel calibration with MSD



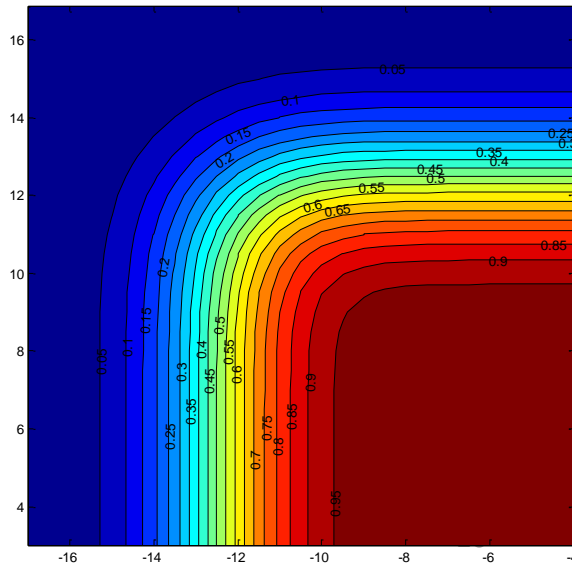
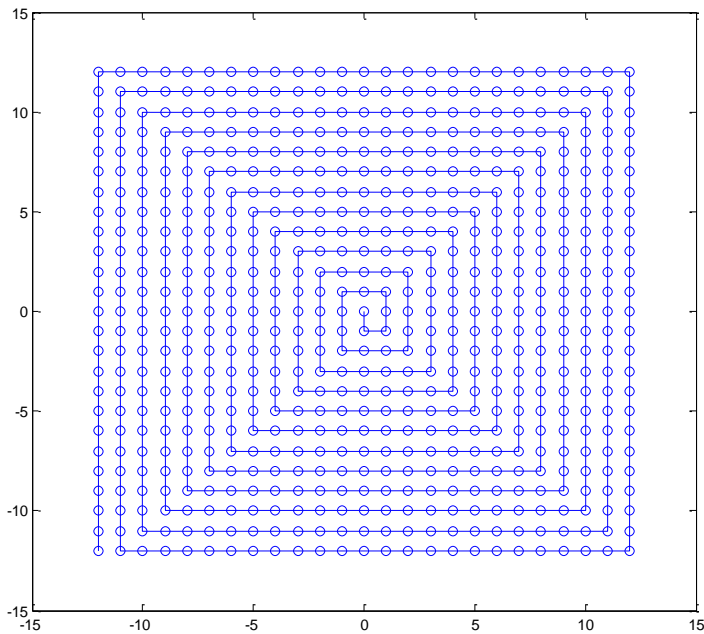
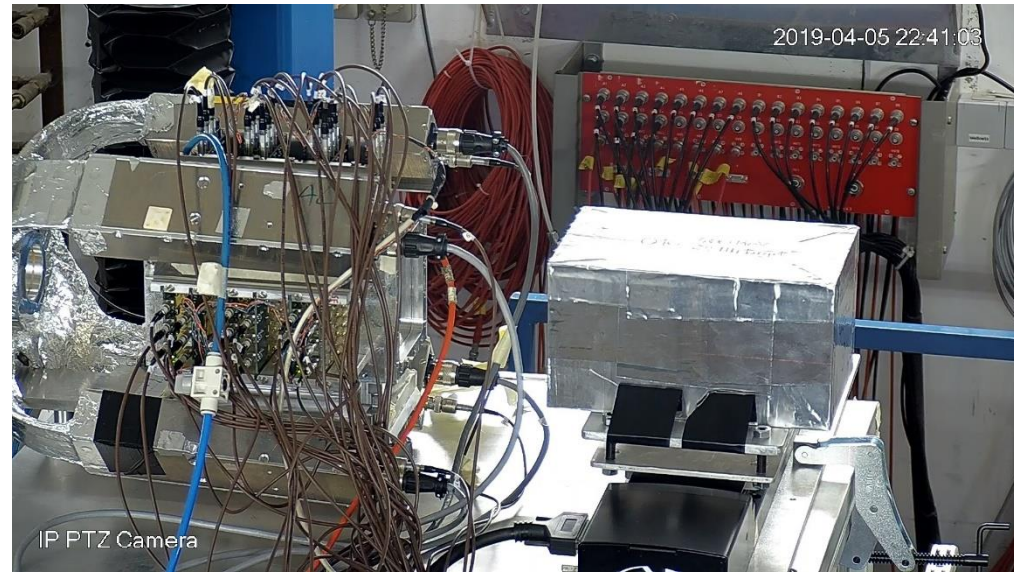
Data Taking @GSI



- IBER beam time 2019 ESA
- Expected 16 hours beam time (parasitic beam)
- Oxygen beam (200 and 400 MeV/u), Cave A
- Two setups: Emulsions + Electronic

Emulsion Setup

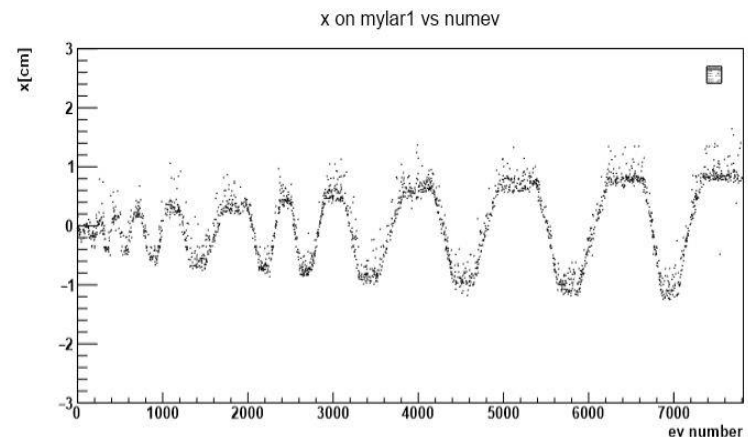
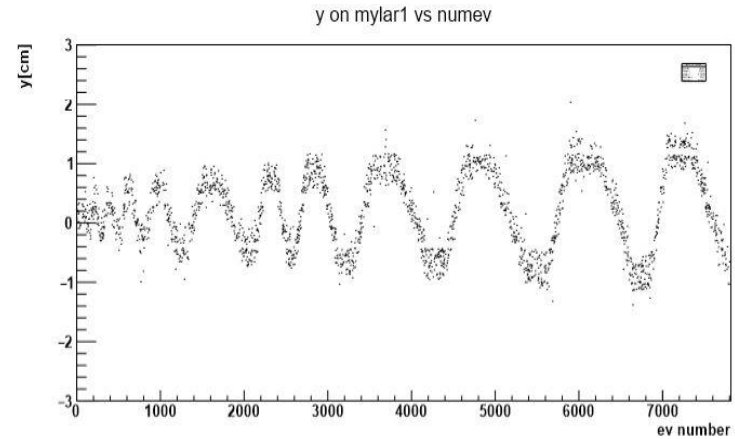
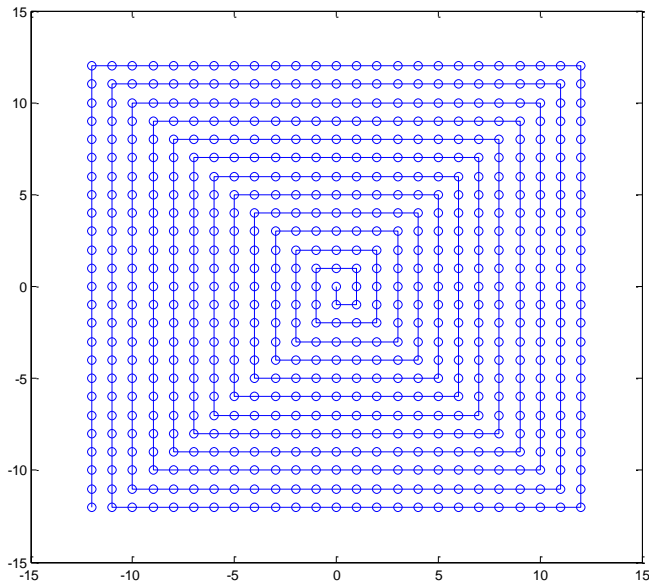
- On-line monitoring: SC + BM
- 4 emulsions chambers exposed
- 200 MeV/u and 400 MeV/u
- Scanned field (2.5 cm x 2.5 cm)
- Overall fluence $14\text{-}19 \times 10^3$ ions



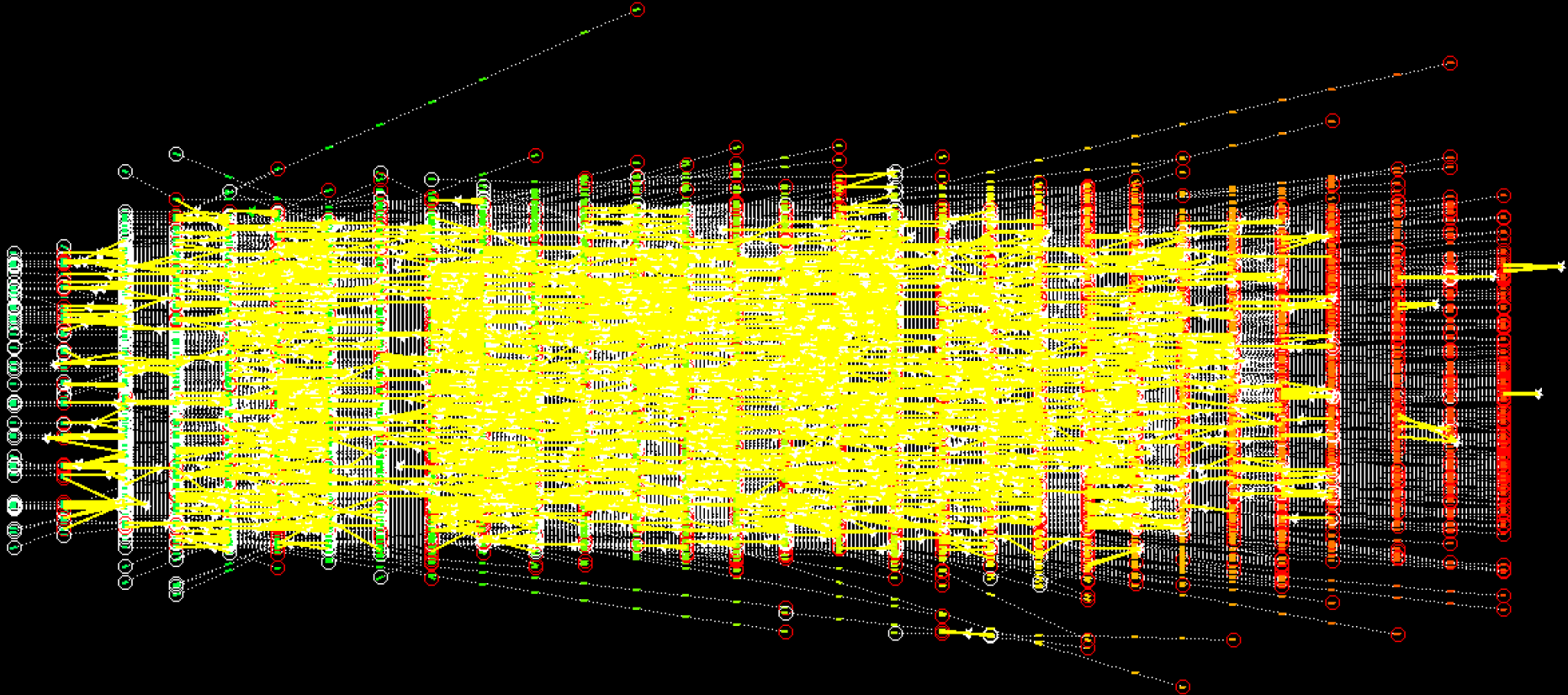
TARGET	BEAM Oxygen 200 MeV/n	Oxygen 400 MeV/n
Carbon	GSI1	GSI3
Polyethylene	GSI2	GSI4

^{16}O @ 400 MeV/n , target: C_2H_4

Esempio di uso del Beam Monitor Scanning of the emulsion surface:
beam position vs. number of events

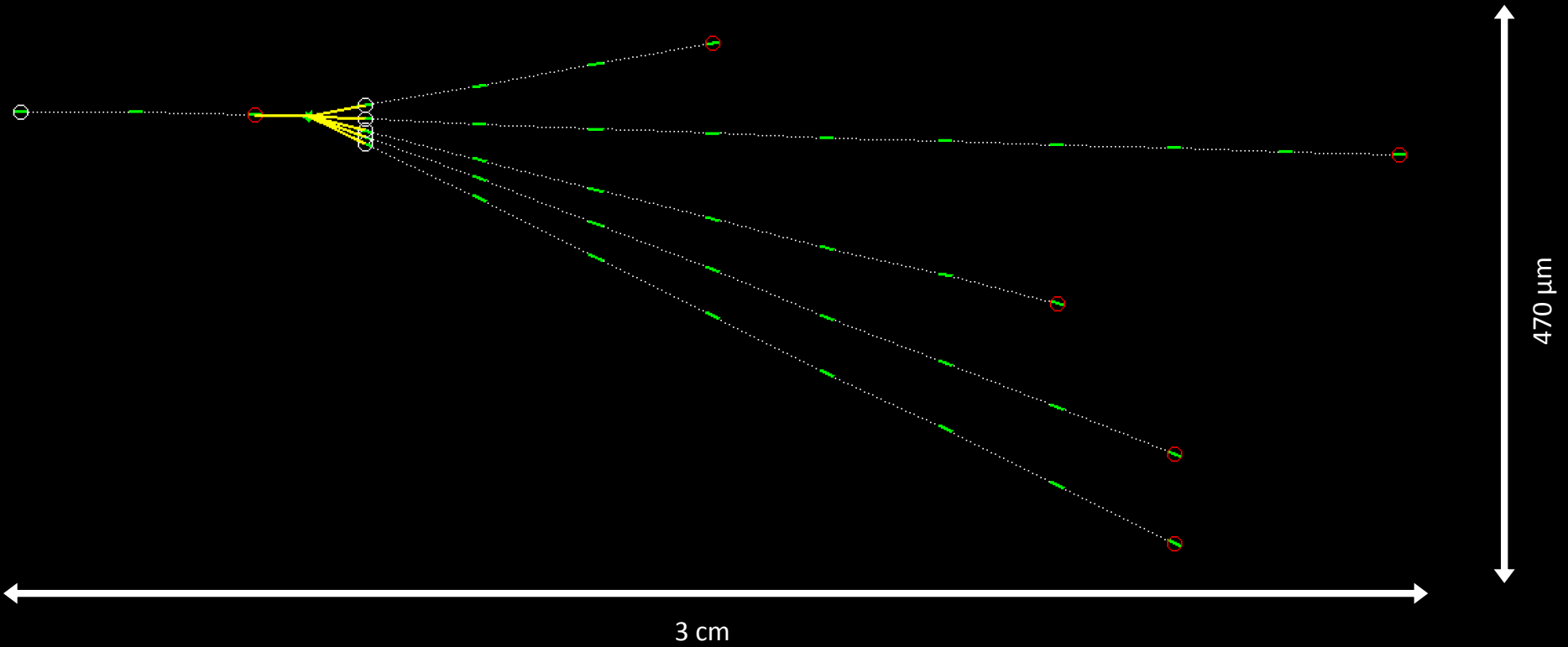


ALL OXYGEN VERTICES

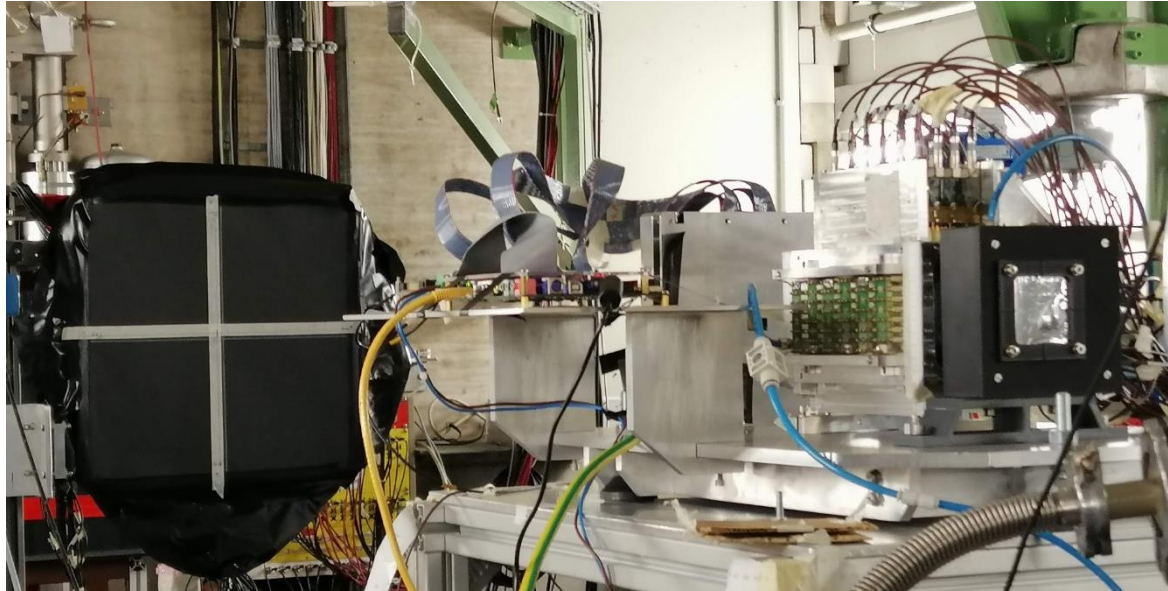


Sistema di scanning con microscopio automatizzato e relativo software su GPU
sviluppato nell'esperienza OPERA

VERTEXING - EXAMPLE



Electronic Setup



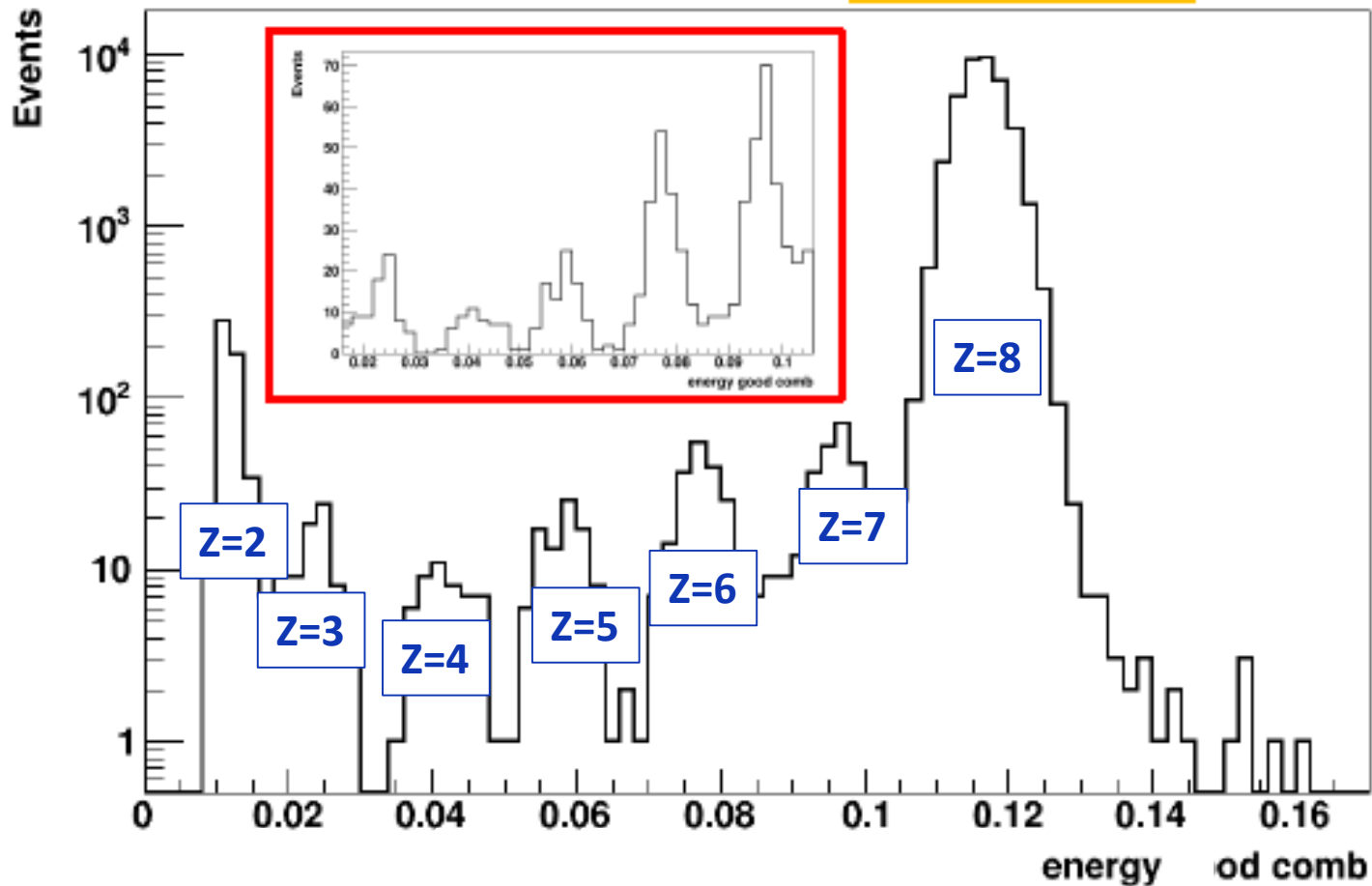
Setup@April 2019:

- SC+BM
- VTX
- TOF Wall
- Calorimeter Crystal

Goal:

- To test integration of sub-detectors in global DAQ
- To test sub-detector performances on Oxygen beam
- ~~- To take at least some data with target (C/C_2H_4)~~

Primi risultati su Z identification (ToF+ dE/dx)

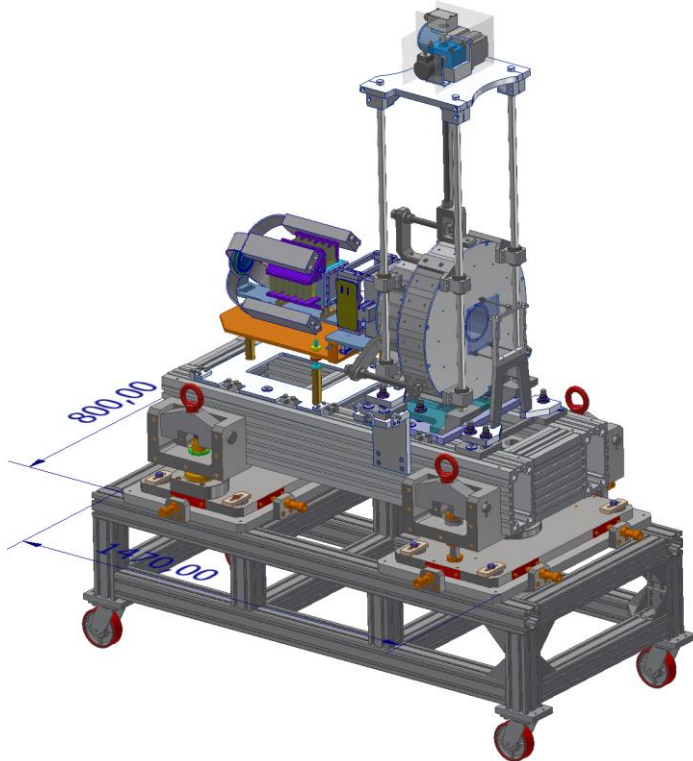
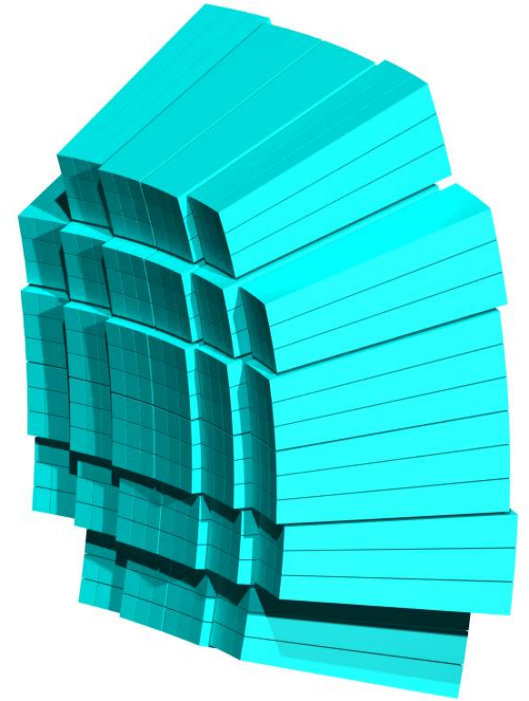


Attività da svolgere nel 2020

Nuova presa dati:

- Con emulsioni al GSI (con $^4\text{He}/^{12}\text{C}$)
- GSI e/o CNAO (nuova sala sperimentale)

Continua il lavoro di sviluppo simulazione e software di ricostruzione



Inoltre (non direttamente come INFN-Milano)

- Finalizzare la gara per i magneti
- Inizio dell'integrazione delle MSD
- Inizio lavoro meccanica (progetto LNF)
- Inizio lavoro sul calorimetro

Necessità di prolungamento oltre il 2020

Completamento apparato (già discusso con i referees):

- Problema nella realizzazione della gara dei magneti
- MSD: delays
- Inner Tracker: soffriamo del problema legato alla vicenda CADENCE
- ...

Difficile completare il programma di presa dati previsto entro il 2020

Non comporta nuova spesa fondamentale, ma diluizione nel tempo di quanto previsto

Richieste Milano 2020

	No.	Persone	Giorni	Richiesta (kEuro)	
Meeting Collaborazion	2,00	3,00	2,00	3,00	
Meeting di lavoro a Roma, Trento, Perugia	2,00	3,00	2,00	3,00	
Presa dati GSI	1,00	2,00	15,00	5,00	
Presa dati CNAO	1,00	3,00	7,00	3,00	S.J.
Totale Missioni				14,00	(11+3S.J.)
Consumo (Beam Monitor operation)				2,00	
Trasporti				0,50	
TOTALE				16,50	

G. Battistoni 50%

I. Mattei 20%

S. Muraro 50%

S. Valle (AR) 70%

Y. Dong (Dott.) 80%

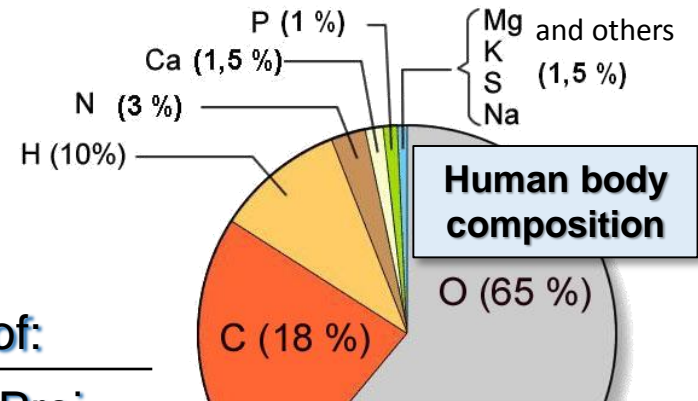
S. Brambilla 10%

+ nuovo dottorando?



BACKUP SLIDES

FOOT: Programma minimo di misure



Beam	Energy	Target	Interest		Fragm. of:	
			PT	RPS	Targ.	Proj.
^{16}O	400 (MeV/u)	H, C, O	✓			✓
^{16}O	700 (MeV/u)	H, C, O		✓		✓
^{12}C	350 (MeV/u)	H, C, O	✓			✓
^{12}C	700 (MeV/u)	H, C, O		✓		✓
^4He	250 (MeV/u)	H, C, O	✓			✓
^4He	700 (MeV/u)	H, C, O		✓		✓
p	200 (MeV)	C, O	✓		✓	

Fragment	E (MeV)	Range (μm)
^{15}O	1.0	2.3
^{15}N	1.0	2.5
^{14}N	2.0	3.6
^{13}C	3.0	5.4
^{12}C	3.8	6.2
^{11}C	4.6	7.0
^{10}B	5.4	9.9
^8Be	6.4	15.7
^6Li	6.8	26.7
^4He	6.0	48.5
^3He	4.7	38.8
^2H	2.5	68.9



Tommasino & Durante (2015)

SIGNAL VS COSMIC RAYS SEPARATION

