GSI Data Taking 2021

When: 15-16 july 2021 (confirmed @80%)

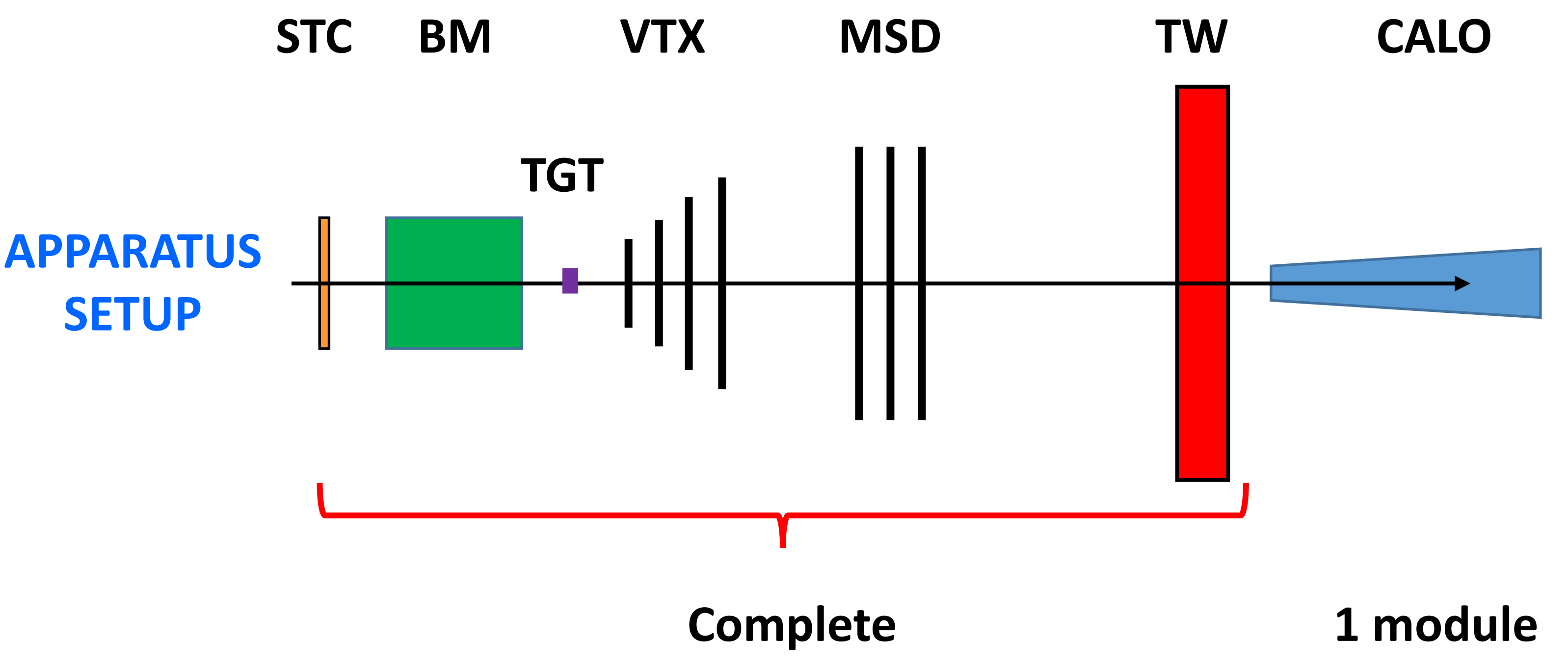
Beam: ^{16}O @200 and 400 MeV/u

Data taking duration: 6 slots of 8 hours each

Beam duty cycle: 50%

Number of primaries (supposing beam frequency 1 KHz) : 1.5 x 10^6 /hour

FOOT acquisition rate: 1 KHz



Time schedule

Mon 12	Tue 13	Wed 14	Thu 15	Fri 16	Sat 17
MOUNT	CABLING and TEST		BEAM	BEAM	DISMOUNT

Mounting

DAQ
TRIGGER
SOFTWARE
DETECTORS

Test, synchronization, acquisition

Ready to start soon when beam ON

MACHINE SETUP:
- move detectors?
  - NO → time 0
  - YES → time?

MEASUREMENTS
- Alignment
- Trigger request
- Calibration
- Physics

ALIGNMENT

WITHOUT TARGET

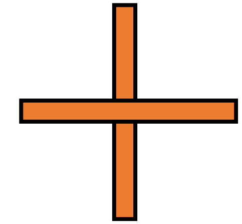
ALL DETECTORS IN PARALLEL

Measurements:

- Alignment, Tests → Statistics: ~30kevts/min ↓ ~15 minutes ↓ ~450kevts (> statistics without Target in GSI 2019) Is it enough?
- evaluate fragmentation in air and in detectors

Time: 15 minute
In the final table quoted 1 hour

TRIGGER REQUESTS



veto on TW central bars when energy deposit is over threshold

Not considered trigger with also another hit somewhere that has more bias

Important: trigger calibration is performed parasitically no dead time

Measurements:

- **Trigger request:**
  - **Step 1**: ~ minimum bias → 1 hour (Useful also for physics)
    - Evaluate the pulse height for TW central channels
  - **Step 2**: apply threshold and restart the run (trigger prescaled)
    - Test different thresholds (1 minute stop for each change)
  - **Step 3**: measure fragmentation trigger rates
  - **Step 4**: start with fragmentation run

Supposing 3 thresholds tested → after 3 hours of minimum bias → TRIGGER ON

After 3 hours → TRIGGER ON

TRIGGER PERFORMANCE

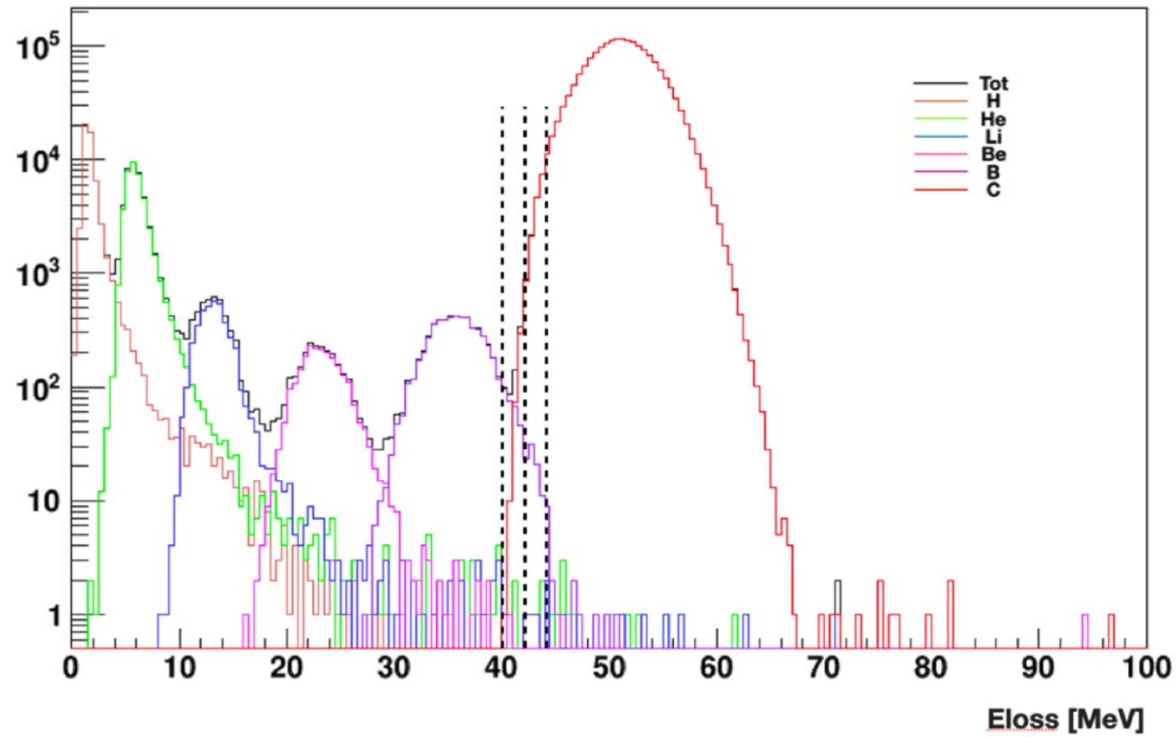
VETO on TW central bars

MC:

- Beam: ^{12}C @200 MeV/u
- Target: C_2H_4

Suppose similar for ^{16}O

3 thresholds: 38–42–46 MeV



- Empty events decrease by factor 10
- Efficiency → 100% for fragments ≠ from beam

In principle we can work with a beam frequency @ 10 KHz but → pile up problems → too many tracks on vtx → increase dead time by a factor ~ 2

beam @ 4KHz → number of interacted events increased by factor 4

CALIBRATION

TOF WALL

- SCAN
  - 2 s per cell → 14 min
  - 3 s per cell → 20 min
  - 4 s per cell → 27 min
  - 4 points per bars → 17 min
  - 5 points per bar → 22 min

  }
  - **All detectors in place**
  - **at the end of the data taking**
- Fragment identification on each cell
  - necessary enough statistics in each cell (problem in periphery?)

0.5 hour → **In the final table quoted 1 hour per target**

CALORIMETER

- Crystal inhomogeneity → better to calibrate all
- How much statistics for each crystal?
- How much time to move detectors?

} **detectors moved from beam?**

Hours ? → **In the final table quoted 2 hours per target**

PHYSICS

	24 h		24h	
Energy	200 MeV/u		400 MeV/u	
Target	C	C_2H_4	C	C_2H_4
Thickness (mm)	5	5 (10?)	5	5 (10?)
Density (g/cm^3)	1.83	0.94	1.83	0.94
Distance Target-TW (cm)	180	180	180 (more?)	180 (more?)

2 possible cross section measurements

NO CALO involved

Only charge determination

Integral charge cross section
Differential charge x sect wrt angle

CALO involved

Isotopic identification

Differential fragment cross section

Integral cross section

Cross section formula

$$\sigma_{i,t} = \frac{Y_{i,t}}{N_p} \frac{A_t}{N_A\, \rho_t\, \delta_t}$$

With:

- $\sigma_{i,t}$ = cross section to produce fragment i on target t [cm^2]
- $Y_{i,t}$ = Number of fragments of type i [ ]
- A_t = molecular mass of target [g mol^{-1}]
- N_p = number of primary particles [ ]
- N_A = Avogadro's number [mol^{-1}]
- ρ_t = density of target [g cm^{-3}]
- δ_t = thickness of target [cm^{-1}]

$$\sigma_{i,C} = \frac{Y_{i,C}}{N_p} \frac{A_C}{N_A\, \rho_C\, \delta_C}$$

$$\sigma_{i,C_2H_4} = \frac{Y_{i,C_2H_4}}{N_p} \frac{A_{C_2H_4}}{N_A\, \rho_{C_2H_4}\, \delta_{C_2H_4}}$$

$$\sigma_{i,H} = \frac{1}{4}\left(\sigma_{i,C_2H_4} - 2\sigma_{i,C}\right)$$

Uncertainty on Cross section depends on statistics

$$\frac{\Delta\sigma_{i,H}}{\sigma_{i,H}} \sim \frac{1.08}{0.33}\frac{\Delta\sigma_{i,C}}{\sigma_{i,C}} \sim 3.3\frac{\Delta\sigma_{i,C}}{\sigma_{i,C}}$$

primary (C_2H_4) = primary (C)

$$\frac{\Delta\sigma_{i,H}}{\sigma_{i,H}} \sim 2.5\frac{\Delta\sigma_{i,C}}{\sigma_{i,C}}$$

primary (C_2H_4) = 2 x primary (C)

$$\frac{\Delta\sigma_{i,H}}{\sigma_{i,H}} \sim 2.1\frac{\Delta\sigma_{i,C}}{\sigma_{i,C}}$$

primary (C_2H_4) = 4 x primary (C)

Integral charge cross section: MC statistics evaluation

MC ^{12}C @200 MeV/u (is similar for ^{16}O) :

- Target C: Target: Z = 5 mm, ρ = 1.83 g/cm^3, A_t = 12, A_t / ρ_t =6.5
- Target C_2H_4: Target: Z = 5 mm, ρ = 0.94 g/cm^3, A_t = 28, A_t / ρ_t =29.8

Z of fragment i	$Y_{i,C}$	Y_{i,C_2H_4}	$\frac{Y_{i,C}}{Y_{i,C_2H_4}}$
1	334288	207099	1.61
2	274852	197885	1.39
3	28158	22329	1.26
4	15405	13240	1.16
5	32617	26699	1.22
6	26183	26396	0.99

Statistics reached with 10^7 primaries for each target

~6+6 hours of Beam time @ 1 kHz, 50% duty cycle with minimum bias

Y(C) > Y(C_2H_4) but σ(C) < σ(C_2H_4) due to A_t / ρ_t

More statistics on C_2H_4 target, to have enough statistics for cross section in H

primary (C_2H_4) = 2 x primary (C) or enlarge the target depth of C_2H_4

NO Statistical problem: for integrated cross section 2+2 hour is enough

Differential fragment cross section

Calorimeter

- evaluate the energy → differential cross section
- Evaluate mass → isotopic identification

⬇

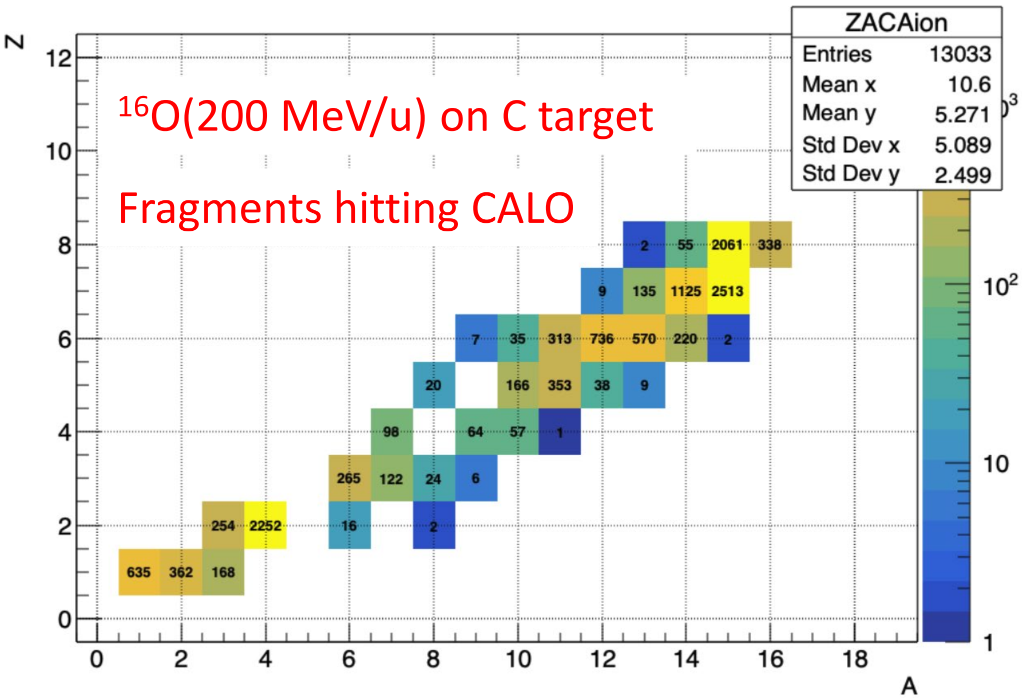
- Solid angle reduction (calo with only 1 module)
- Z reconstruction:
  - 1MeV thereshold on TW
  - Same E loss (inside 5%) in front and rear slab
- Mass reconstruction: 10 MeV thereshold on CALO
  - Sum over 4-6-9 crystals
  - Not considered non-homogeneity of the Calo

$$A = \frac{E_{calo}}{931.5(\gamma - 1)}$$

Differential fragment cross section: 200 MeV/u

MC sample: ^{16}O(200 MeV/u) on C and C_2H_4 targets

Statistic: 10^6 primaries (**~ 40 minutes of minimum bias**) for each target



C target

Z	TW	CALO %TW
1	1165	7
2	2524	11
3	417	16
4	220	17
5	586	33
6	1883	45
7	3782	87
8	2456	72

C_2H_4 targets

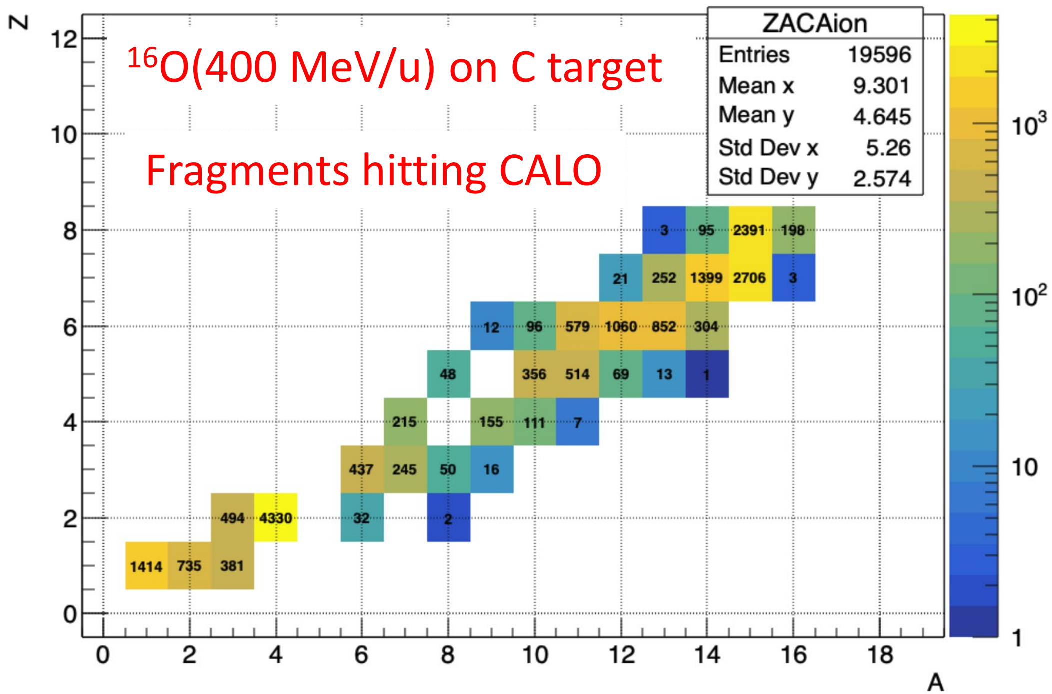
Z	TW	CALO %TW
1	870	6
2	2181	10
3	332	13
4	188	16
5	545	31
6	1867	46
7	3085	74
8	2706	82

We have to decrease these numbers by the reconstruction efficiency

Differential fragment cross section: 400 MeV/u

Statistics evaluated on MC sample: ^{16}O(400 MeV/u) on C and C_2H_4 targets

Statistic: 10^6 primaries (**~ 40 minutes of minimum bias**) for each target



C

Z	TW	CALO %TW
1	2530	7
2	4858	15
3	748	25
4	488	32
5	1001	61
6	2903	78
7	4381	94
8	2687	96

C_2H_4

Z	TW	CALO %TW
1	1761	7
2	4207	18
3	669	28
4	415	33
5	999	57
6	2725	71
7	4387	91
8	2946	94

We have to decrease these numbers by the reconstruction efficiency

In general:
- Yeld (400 MeV/u) > Yeld (200 MeV/u)
- σ (400 MeV/u) < σ (200 MeV/u)

Scenario 1: use only Minimum bias

1	2	3	4	5	6	7	8
Machine setup		Alignment	Physics C target				

1° slot

1	2	3	4	5	6	7	8
Machine setup	Physics C_2H_4 Target						

2° slot

1	2	3	4	5	6	7	8
Machine setup	Physics C_2H_4 Target			TW calibration	Calo calibration moving out all detectors		spare

3° slot

All acquired events with minimum bias

decrease these numbers by reconstruction efficiency

If target depth 1 cm
→ statistics doubled

^{16}O(200 MeV/u)

Z	C	C2H4
1	8700	13000
2	19000	32000
3	3100	5000
4	1600	2800
5	4400	8000
6	14000	28000
7	28000	46000
8	18000	40000

^{16}O(400 MeV/u)

Z	C	C2H4
1	19000	26000
2	36000	63000
3	5600	10000
4	3600	6200
5	7500	15000
6	21700	41000
7	33000	65800
8	20000	44000

Scenario 2: use of trigger

1° slot

1	2	3	4	5	6	7	8
Machine setup		Alignment	Physics C target Minimum Bias			Physics C target TRIGGER	

2° slot

1	2	3	4	5	6	7	8
Machine setup	Physics C_2H_4 Target Minimum Bias			Physics C_2H_4 Target TRIGGER			

3° slot

1	2	3	4	5	6	7	8
Machine setup	Physics C_2H_4 Target TRIGGER			TW calibration	Calo calibration moving out all detectors		spare

decrease these numbers by reconstruction efficiency

If target depth 1 cm
→ statistics doubled

^{16}O(200 MeV/u)

Z	C	C2H4
1	12800	27000
2	27700	67000
3	4600	10000
4	2400	5800
5	6400	17000
6	20700	57000
7	41600	95000
8	27000	83000

^{16}O(400 MeV/u)

Z	C	C2H4
1	27800	54000
2	53000	130000
3	8200	20000
4	5300	12800
5	11000	31000
6	31200	84000
7	48000	135000
8	29000	91000

Conclusions

Am I missing something?