DP status

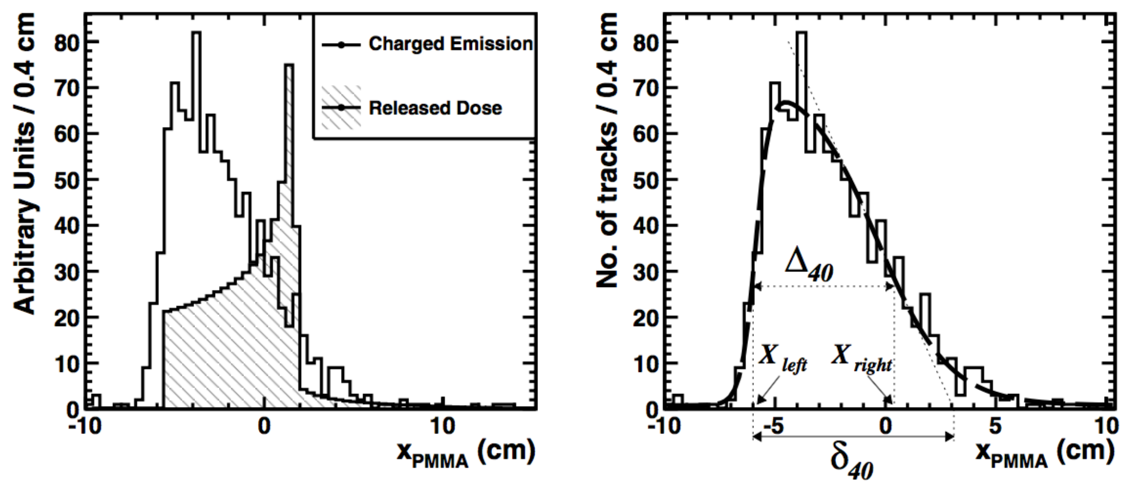
CNAO jul 2017

➡ Data taking conditions

The 'final problem'

- In clinical case conditions.. are we going to have enough tracks to perform our 'online monitoring'?
  - How many fragment exit?
  - What is the rate in clinical case conditions? (DP developed to sustain @ 10 kHz rate)

The L. Piersanti *et al* statement:
1k tracks in homog target → 3 mm resolution on BP



Data @ 90°

- ➡ Using @ 90°: run 'rundo*87'
  - taken 25 07 @ 2:45. DD log file: *_004120_QA/beam4fluka.txt .
    - **#^{12}C 0.99 10^9;**
    - data taking time: 27s;
    - #events reconstructed:1.1 10^5;
    - #total tracks: 1. 10^5;
    - number of tracks from RANDO 7.9 10^4

@90° the DP was placed @ 46cm from TGT

- ➡ Conservative approach (CA): use the number of tracks from RANDO. Best case scenario (BCS): use the number of events.
  - CA: 8 10^4 tracks for 10^9 carbon ions
  - **BCS: 10^5 tracks for 10^9 carbon ions**

		RANDO	Fix1_C_C_20170725_004120_QA	FIX (0,0)	221	999983480	27.0669		87	108555	100786	79421

Data @ 60°

- Using @ 60°: run 'rundo*104'
  - taken 25 07 @ 4:23. DD log file: *_021906_QA/beam4fluka.txt .
    - **#^{12}C 0.99 10^9;**
    - data taking time: 27s;
    - #events reconstructed:1.16 10^5;
    - #total tracks: 1. 12 10^5;
    - number of tracks from RANDO 9.5 10^4

@60° the DP was placed @ 1m from TGT

- Conservative approach (CA): use the number of tracks from RANDO. Best case scenario (BCS): use the number of events.
  - CA: 1 10^5 tracks for 10^9 carbon ions
  - **BCS: 1.2 10^5 tracks for 10^9 carbon ions**

Small difference btw raw 90° and 60° [DT is not accounted for, no solid angle correction is applied]

	DP@60º	RANDO	Fix1_C_C_20170725_021906_QA	FIX (0,0)	221	999994176	27.4010		104	116690	112569	95112

Carbon ions scenarios

- To understand how many tracks are expected in real life conditions we have different options:
  - Take as input a PB/slice in a given **real** treatment plan.
  - Take as input a PB/slice in a **simulation** in which a 1Gy dose was shot in water cube.
- Real treatment plan input:
  - @ 220 MeV: Tot of 13 10^6 in 154 single PB (spots). Particles per 'slice': 1.3 10^7 and particles per PB: **8.5$10^4$**.
- Giuseppe TP for 1Gy dose in Water cube:
  - Last slice (223.56 MeV/u) at ~10 cm of depth: 7.5 10^7 total, **3.3 10^5 per PB**, (8.3 10^6 in 0.2 cm x 1 cm^2)
  - First slice (186.57 MeV/u) at ~7 cm of depth: 7.3 10^6 total, 3.2 10^4 per PB (8.1 10^5 in 0.2 cm x 1 cm^2)

Track yield estimate @ 90°

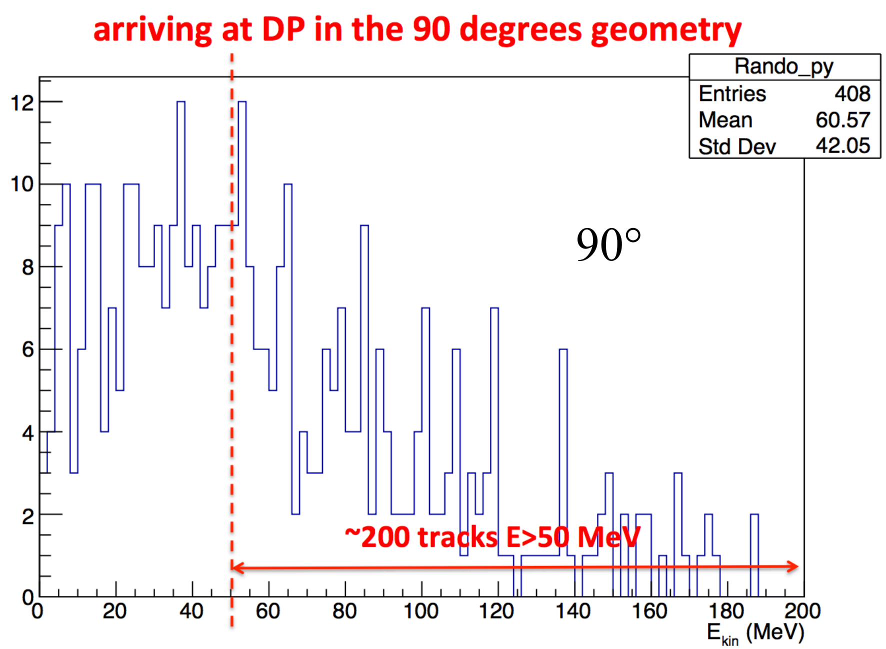
	real TP, PB	real TP, slice	water TP last slice, PB	Water TP last slice, slice	Water TP, last slice, 1cm2	water TP first slice, PB	Water TP first slice, slice	Water TP, first slice, 1cm2
CA	7	1k	26	6k	664	3	580	65
BCS	8.5	1.3k	33	7.5k	830	3.2	730	81

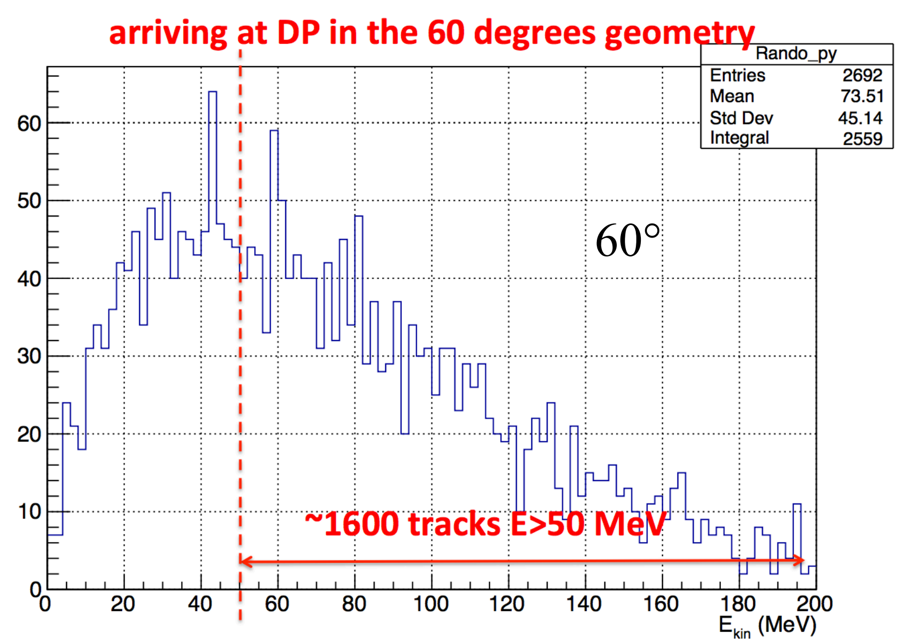
To get what happens @ 60° in nominal conditions remember the following factors: x1.2 [ratio of charged production in DP as measured from data] and x4.7 [solid angle scaling factor].

DT has to be accounted for!

90° vs 60° (MC)

- Simulation from Giuseppe suggests that comparing 90° and 60° tracks exiting from RANDO a factor ~ 8 is expected (this is without accounting for DT!).
  - Different solid angle in MC can be accounted for rescaling 'by hand' the flux **/4.7** to get the expected rate @ data taking pos.
  - Have also to account for the DT impact





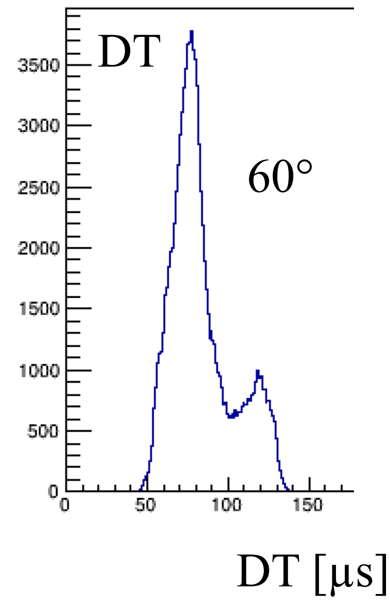
Our main concern: Dead Time

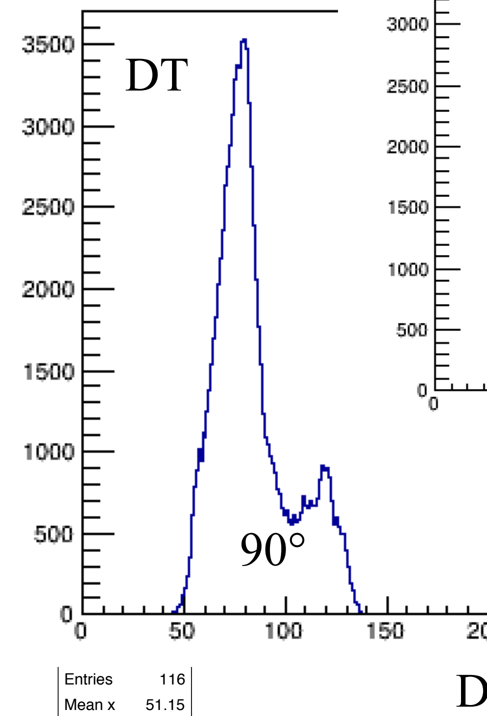
Rate expectations

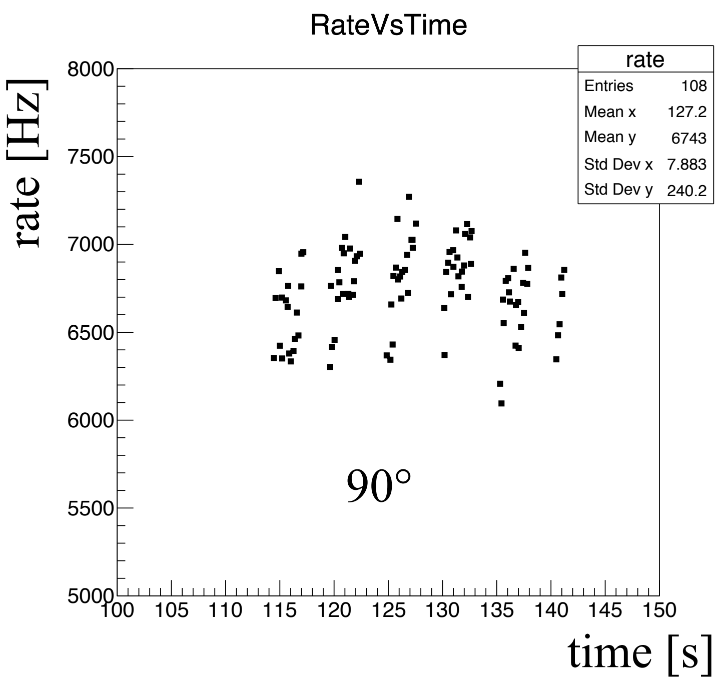
- Calculations based on MC expectations (a factor 2 is allowed in both directions… x2 .. /2):
  - @60° we have 1.5k tracks per 10^6 primary 12C ions
  - @90° we have 0.2k tracks per 10^6 primary 12C ions
- **From the DD log file** we see that:
  - both @ 90° and 60°: ~0.7 10^8 ions per second are shoot. [**data**]
  - Conservative Assumption: assume 1 10^8 ions per second
- The corresponding rates, from MC expected in the DP are:
  - 150 kHz @ 60° [in nominal position], **30 kHz @ 1m from RANDO**
  - **20 kHz @ 90°**
- The DP has been developed, aiming for a 10 kHz max rate. The DT optimisation has not been done yet.

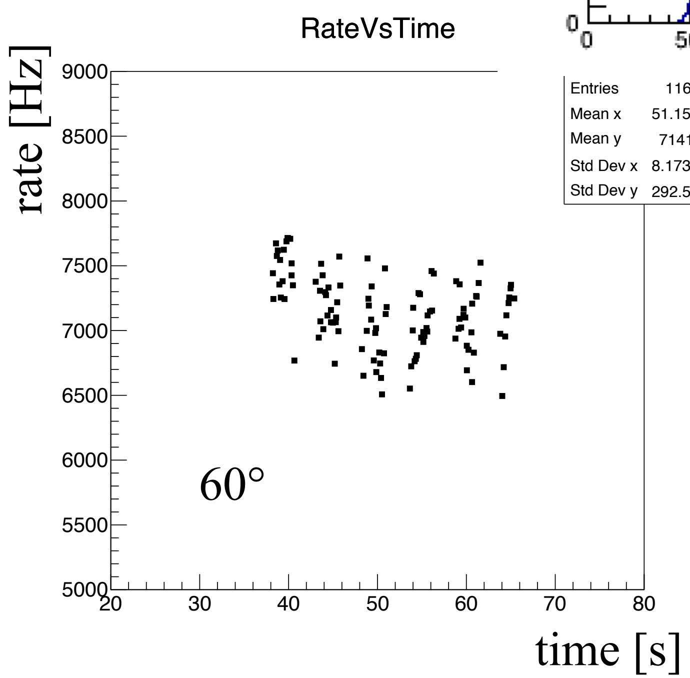
DT, data @ 90°

- The measured DT in the 90° and 60° run is, in average, **83 μs with very similar spectra in both cases**.
- Average **DP rates are 6.7 kHz and 7.1 kHz in the two cases**



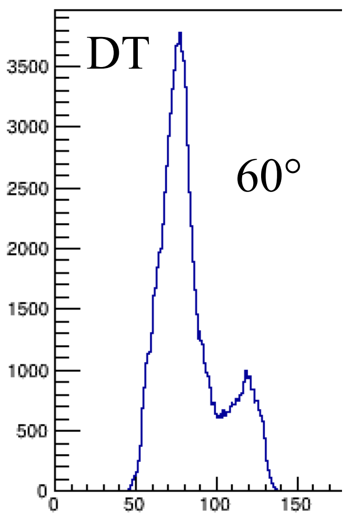




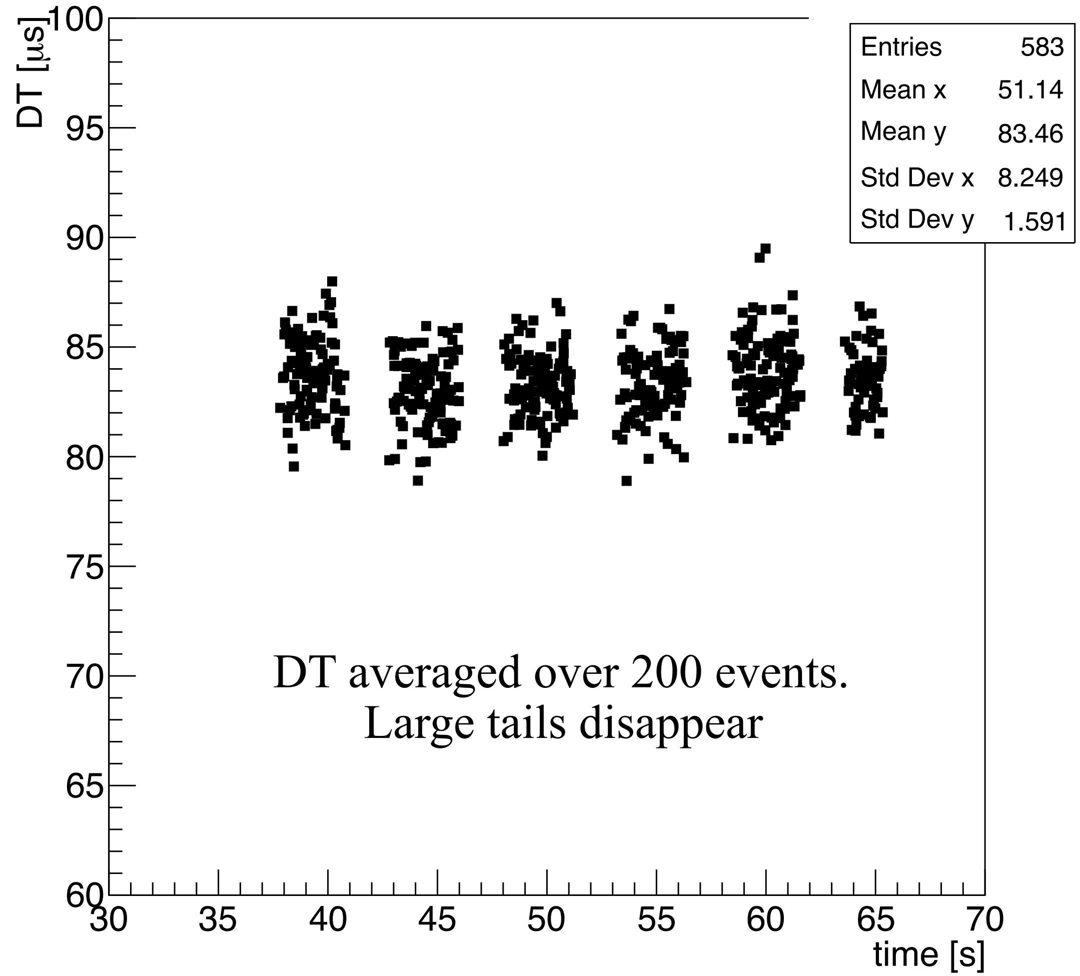


DT vs time

- Run @ 60°
- DT has no evident correlation with time.



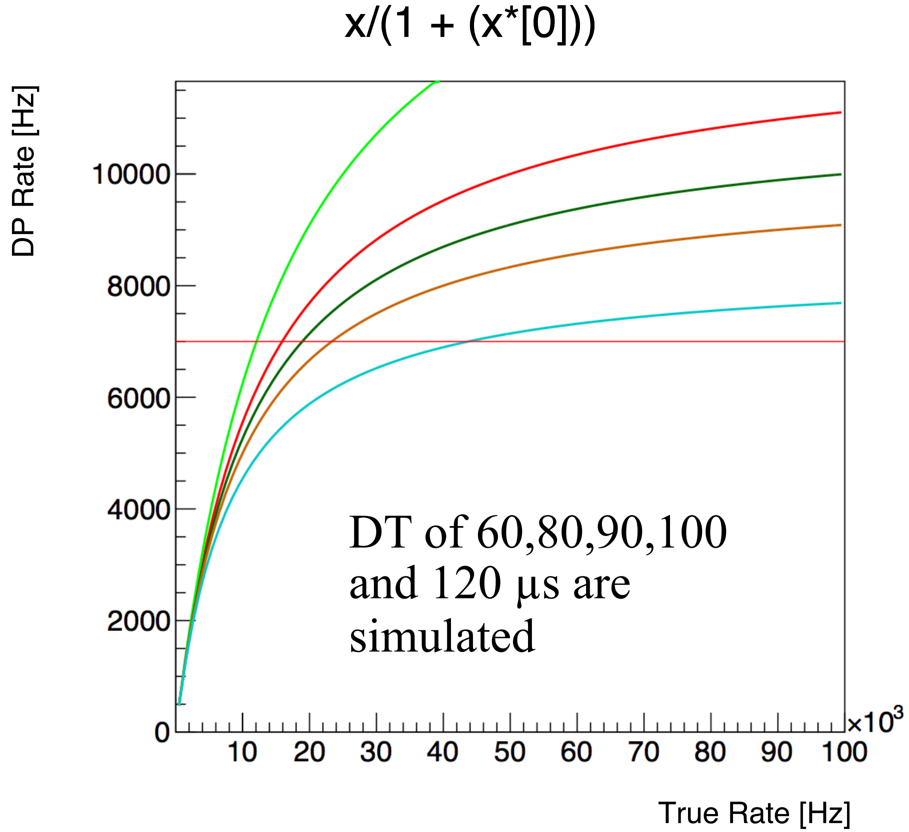
DT [μs]



Dead time

- The impact from the measured dead time (~80 μs) and the measured rate can be guessed from the formula on the right
  - For a DP rate of 6 kHz and 80μs DT we are between 10 and 20 kHz incoming rate….
  - For a DP rate of 7 kHz and DT of 120 μs very large rates (~ 60 kHz) are compatible

Calculation the rate after the dead time using:



To be kept in mind…

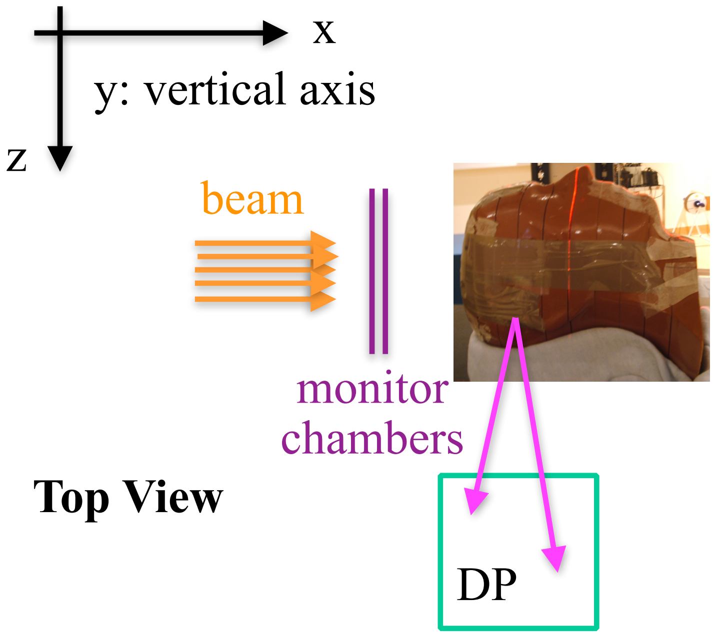
- That a ‘zero DT’ option is not what we have to compare to. We can assume that a DT of 20 μs is a sensible goal and evaluate in ‘nominal’ 60° conditions, what is the impact of such DT.
- Idea:
  - take the data with the current DT, correct for the ‘event by event’ value and get the real rate, rescale for the solid angle @ 60°, guess the ‘true rate’ expected @ 60° in nominal position and apply a 20μs dead time correction. The ratio btw the measured rate and the nominal rate @ 20μs DT will tell us the gain that we can expect….
- The multiplication factors for 20μs DT are: 1.83 @ 90° and 4.4 @ 60°.
  - Factors @ 10μs and 0 DT have been computed as well, for reference:
    - @10μs factors are: 2.1 and 6.3
    - @ 0 μs factors are: 2.5 and 11.7

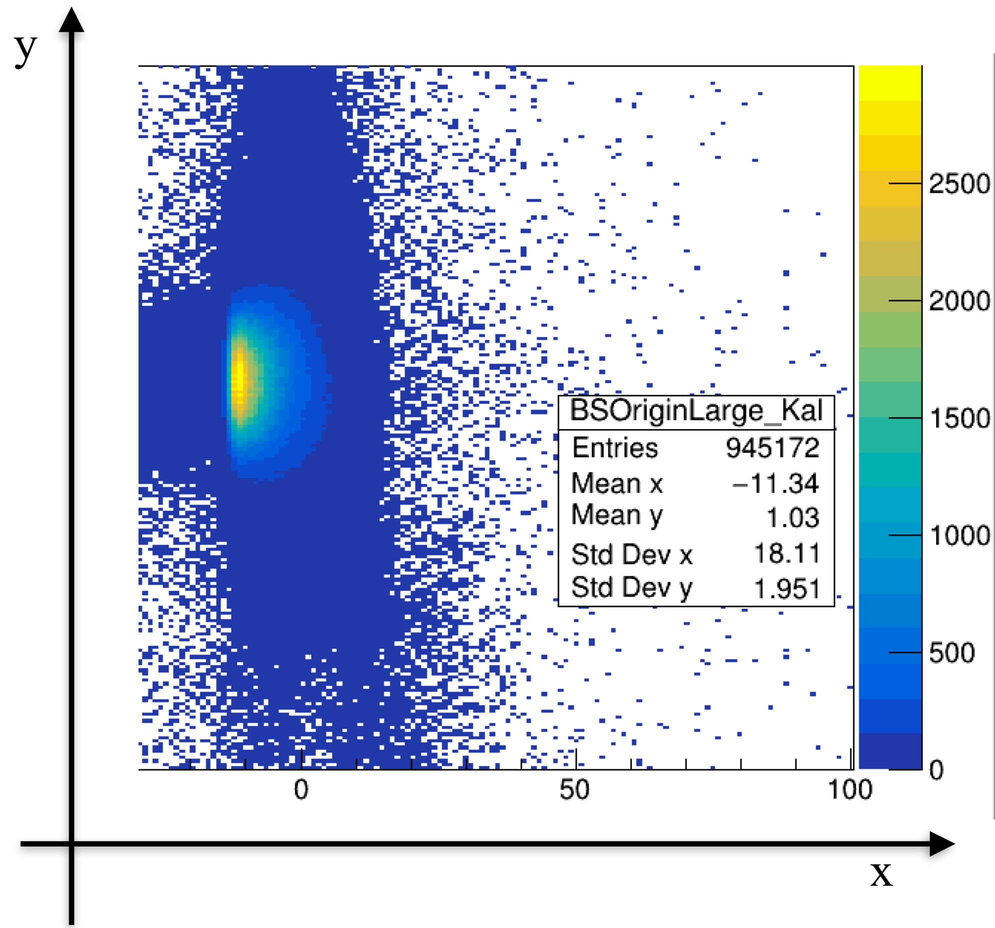
Track yield estimate @ 90°

	real TP, PB	real TP, 9PB	real TP, slice	water TP last slice, PB	Water TP last slice, slice	Water TP, last slice, 1cm2	water TP first slice, PB	Water TP first slice, slice	Water TP, first slice, 1cm2
BCS	8.5	77	1.3k	33	7.5k	830	3.2	730	81
BCS 20μs , 60°	37	333	5.7k	145	33k	3.6k	14	3.2k	360
BCS 10μs , 60°	53	476	8.1k	207	47k	5.1k	20	4.6k	515
BCS 0μs, 60°	100	885	15k	386	87k	9.5k	37	8.6k	960

Not only numbers…

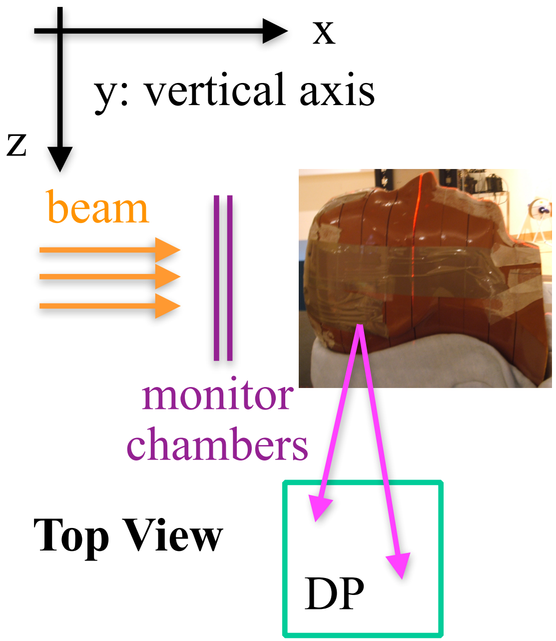
➡ we gave anyway a first look at the track distributions…



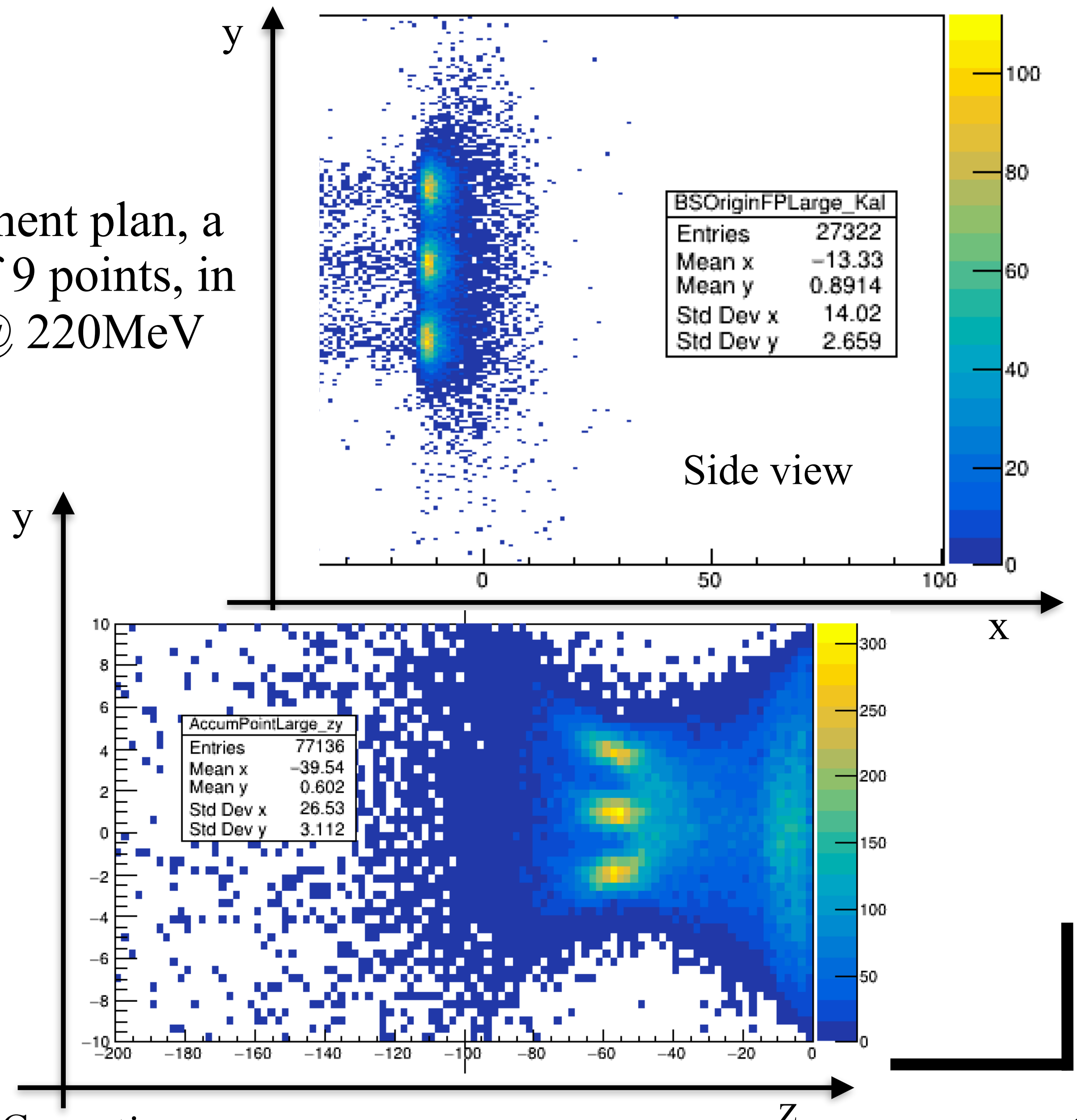


A dose **cube** shot inside the anthropomorphic phantom

.. also track distributions



Treatment plan, a grid of 9 points, in x,y @ 220MeV



Preliminary (rough) attempt of pencil beam standalone reconstruction using POCA of tracks from consecutive events.

Next steps

- Check against thin target (with arms data) and against PMMA thick target (against HIT and GSI measurements) that we see a number of tracks that is consistent with what expected. This is the final proof that we have the full chain under control
- Go trough the data collected and understand the correlation with DD information
- Check the Emission spectra and try to get an estimate on the BP position precision achievable with RANDO data.

Other info (for future)

90° vs 60° (data)

- On thick target what have we measured? Not a big difference…

$$\Phi_p^{90^\circ} = (4.90 \pm 0.06_{stat} \pm 0.57_{sys}) \times 10^{-3}\ sr^{-1}$$
$$\Phi_d^{90^\circ} = (0.70 \pm 0.02_{stat} \pm 0.12_{sys}) \times 10^{-3}\ sr^{-1}$$

$$\Phi_p^{60^\circ} = (11.28 \pm 0.05_{stat} \pm 2.30_{sys}) \times 10^{-3}\ sr^{-1}$$
$$\Phi_d^{60^\circ} = (2.15 \pm 0.02_{stat} \pm 0.44_{sys}) \times 10^{-3}\ sr^{-1}$$

From reanalysis GSI paper.

Keep this in mind when trying to interpret the flux @ 60° predicted by MC in RANDO runs

Grid

- LOG fixed pos 150
- LOG fixed pos 150
- LOG fixed pos 220
- Run 99 *_022220_QA/beam4fluka.txt 9x9 Grid 280 MeV.

Energy scan

- *_025045_QA/beam4fluka.txt
- Fixed pos.
- 115 MeV ->> 400 MeV

Energy scan

- *_025550_QA/beam4fluka.txt
- Fixed pos.
- 60 MeV ->> 226 MeV

Grid @ 118 MeV

- *_033127_QA/beam4fluka.txt
- Energy:

Grid @ 257 MeV

|h0426| (105) 280 MeV/n, DP 60°, matrice, 10^8 primari/spot
rate ~10 kHz, 120k ev

Negli ultimi 4 run la distanza tra il DP (messo a 60°) e
Rando era di 109 cm.

- *_034038_QA/beam4fluka.txt
- Energy: 257.500000
- Tot particles 1800176767 [griglia.]

DDD 220 MeV

- 220 MeV
  - Rando:

run			*#carboni*	*time*	*#ev DP*	*#tracks*	*#tracks rando*
RANDO 85	***bomba, preso il 25 luglio alle 2:25***	`*_002724_QA/beam4fluka.txt`					
RANDO 86	***bomba, preso il 25 luglio alle 2:30***						
RANDO 87	***preso il 25 luglio alle 2:45***	`*_004120_QA/beam4fluka.txt`	***0.99 10^9***	***27s***	***1.1 10^5***	***1. 10^5***	***7.9 10^4***