Monitoring con particelle cariche: stato del dose profiler e prospettive

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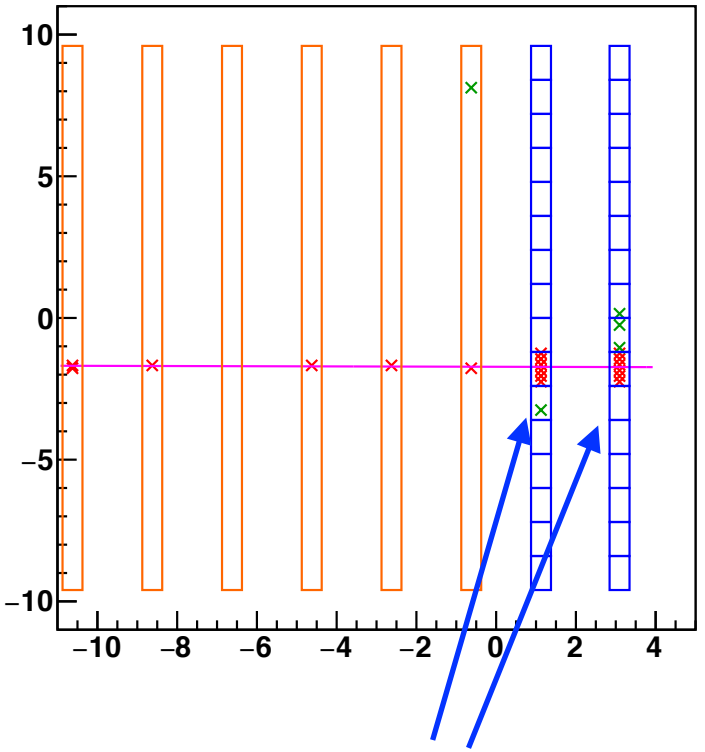
Status: HW activities

- In order to be ready for the next DAQ campaign, the DP needs to undergo few modifications and tests:
  - Scintillator planes replacement with fibre planes [details in next slides]
  - Cooling plate replacement: needed to improve cooling capacity and tightness
- **After** these first two major HW activities have taken place the **detector has to be switched on again and checked/ calibrated**.
- HW/Tests needed for 'clinical conditions' data taking:
  - Cooling system deployment btw tech. room and INSIDE, with 'special' pipes
  - Firmware: DDS driven data transfer has been implemented and needs to be tested. [details in next slides]
- If everything goes as planned, in June we should be ready to take data in final conditions with the final cooling system

Fibres instead of scintillators

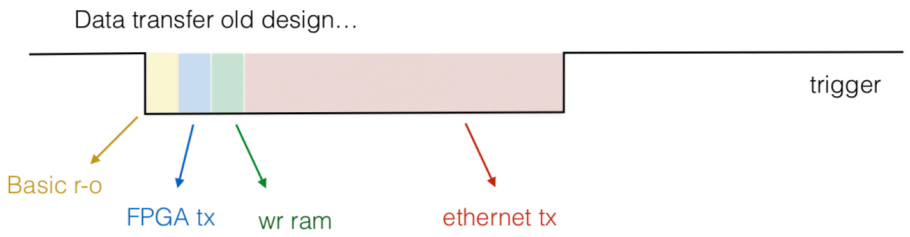
- Currently the scintillator bars in planes 6,7 of the DP are used only as a mean to improve the energy resolution on the incoming tracks.
- It turned out that:
  - the amount of data that has to be transferred is causing dead time.
  - the energy info is not needed to select the 'best tracks' for backtracking..
- In order to reduce the impact on the dead time, the planes of scintillators will be replaced with planes of fibres allowing to:
  - add 2 points in the tracking (improving the resolution)
  - reduce the data to be transferred for each event

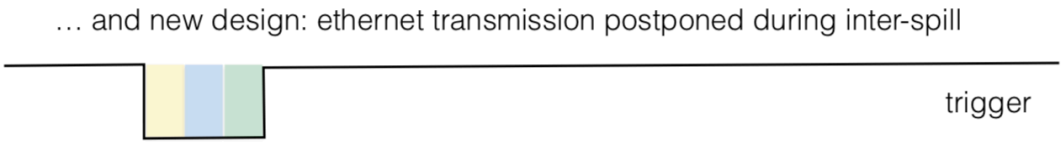


Scintillator bars, to be replaced with fibre planes

DDS driven data transfer

- A crucial improvement needed to reach the target resolution on BP position is to minimise the dead time impact on the collectable statistics
- Currently we are limited to ~1/10 or less of the available statistics:
  - Firmware has been re-checked and re-optimized to collect and transfer the data at the highest possibile rate.
  - To avoid data loss data will be packed 'during the spill' and transferred when the beam is off ('off-spill'). Technology is already in place, and lab test have been performed: we need a final test in a real-case scenario @ CNAO using the DDS signals to verify that everything goes as planned.

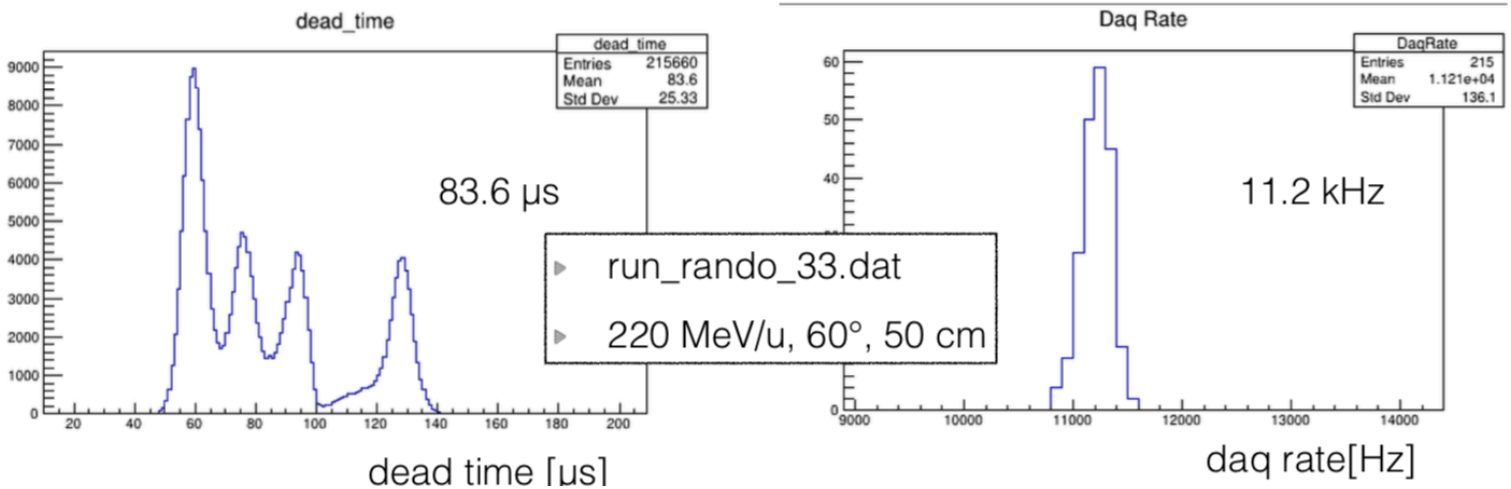




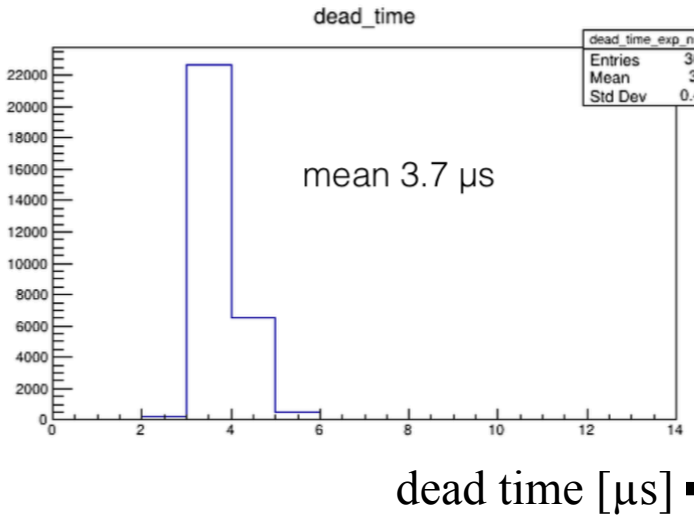
DDS driven data transfer

- The events will be packed/stored inside the RAM, and transferred once we are 'off-spill'

Current situation:
$R_m/R_t = 0.062$



After DDS driven deployment (and event size reduction): expected $R_m/R_t \sim 0.6$



$$\frac{R_m}{R_t} = \frac{1}{1+\tau R_t} \sim 0.6$$

- 4.2 10^5 # of trigger/spill
- ~40 Mbyte

Affordable data size to be transferred within the off-spill time

Cooling

- Project has been defined, pieces will be ready to be ordered in 10 days, will be available (once the order has been placed) in 5 weeks.
  - Finalised today the design of the connection btw the chiller and the DP using coated tubes and fast connection with valves that can be used with small water flows.
- The replacement of scintillator planes and cooling system started in Apr 4th (yesterday!) and is expected to last 3 weeks. After that, a full re-check of the detector connections, response and a detector calibration will be needed.

HW tests

- In order to be ready for the clinical trial, the DDS driven data taking, and the impact of the HW replacements has to be tested @ CNAO in 'clinical-like' conditions.
  - We have already requested the beam time , in May - June, to perform such tests.
  - While we do not expect any showstopper from this test, it has to be stressed that it is mandatory to perform such tests (and check that everything behaves as expected) **before** including the DP in any clinical trial.

Status: SW activities

- The DP resolution studies are being finalised.
  - A new, improved, simulation of the detector response has been deployed and will be tested in the coming weeks.
  - A single track resolution of 8mm @50 cm is becoming a 'solid' result. Given the reduced statistics available per PB [to be finally assessed after reducing the DT impact], it is crucial to explore, **in the future**, different geometrical conditions for the DP data taking. Data taking **at smaller distances wrt patient** should be explored in clinical-like conditions to test the technique potential.

	σ^X	σ^Y
MC Panduit 220 MeV/u	8.3mm	7.9mm
Sfera 220 MeV/u	8.8mm	6.5mm
Capello 220 MeV/u	8.6mm	7.4mm

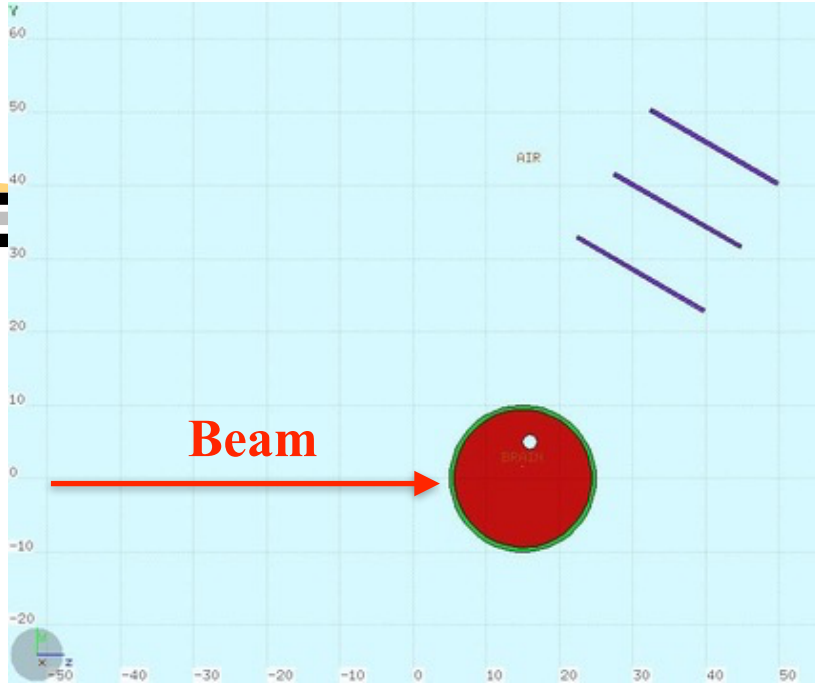
The fragments 'low' energy explains the worsening of the resolution wrt what measured @ Trento with monochromatic 70 MeV proton beams

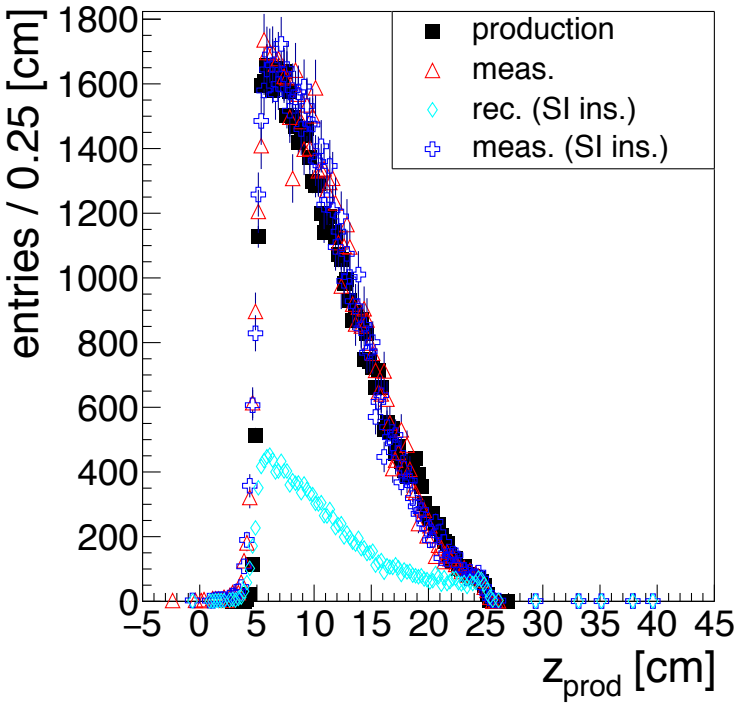
Status: SW activities

- To say a final word on the BP monitoring, the matter effects have to be taken into account: absorption inside the matter and different production cross sections in different materials have to be accounted for when correlating the measured spectra with the emission one (and hence with the BP)
- In order to assess the precision achievable on the BP monitoring using charged particles, we already have the necessary data (collected @ CNAO in 2017) with the DP in the nominal 'INSIDE' position: **we are finalising the 'matter effect' study to gain access to the secondary emission profile** (starting from the measured one) and study the correlations with the BP position.

Matter effect: status

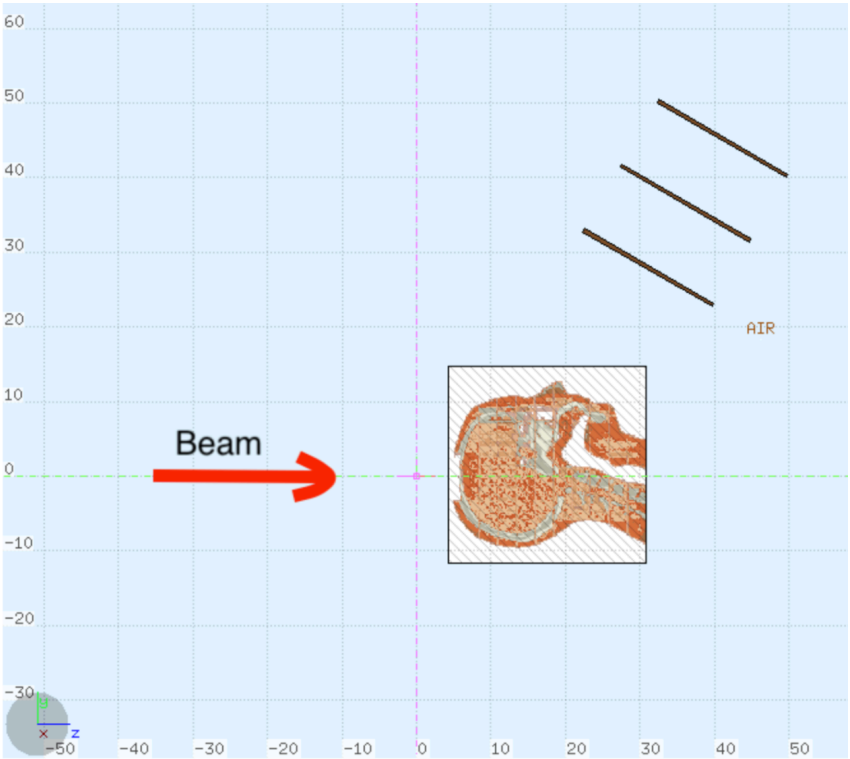
- A simplified problem: the 'Mental Ball'
  - What if I shoot a beam inside an inhomogeneous material, and I collect the secondaries with some detectors @ some distance? Can I regain access to the emission spectra by modelling the secondary interactions with matter @ different production depths and depths of traversed material?
- Developed a re-weighing algorithm that accounts for the matter effects and gets back the production spectra from the reconstructed one!
  - Validation against RANDO is ongoing: more difficult due to large 'point to point' inhomogeneities in the traversed material





Matter effect: outlook

- In order to address the 'full' problem..
  - further studies are needed..
    - FLUKA: Validation of a 2D approach (re-weighing based on emission point and traversed material) is ongoing
    - FLUKA: Deployment of a full 3D approach (considering also the emission angle) is being considered.
    - FRED: Deployment of an MLEM-based re-weighing approach is ongoing and will be benchmarked (as a first attempt) with the results obtained with the 2D and 3D reweighing algorithms



MLEM will be based on FRED computing power for the backtracking of a large sample of protons using the CT information to build the MLEM matrix in affordable times

Clinical trial: the DP perspective

- Once the HW tests will be performed @ CNAO, the DP will be technically available for the clinical trial…
- However, there are few important things that have to be stressed:
  - It will be, likely, the first data taking performed after the 'rebirth' of the detector: no 'online' analysis will be available and **some time (~months) will be needed to process the data,** run the simulations and **get some feedback**
  - The DP will profit from any data taken in the clinical trial, provided that there will be some CT reference available for the data analysis: however we are not in the phase in which we need to assess the performance of the detector against a large statistics nor a full patient history. While taking such data is obviously interesting, it should be stressed that the DP still needs a significant software and analysis effort in order to benchmark his performance and provide an useful feedback for the treatment evaluation. **Before going for 'statistics accumulation' the DP needs to finalise his proof-of-principle exercise** [even against 1 single patient]

Clinical trial: the DP perspective

- We are particularly interested in the possibilities to explore different 'in room' positions of the DP
  - The clinical trial will be a perfect occasion to perform such tests: during the night we can profit from the detector presence @ CNAO to arrange some 'standalone' tests that will definitely provide valuable input for the charged particles monitoring technique validation.