Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

LAPPD Project
Test Beam Facility MC6-7 Simulation

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Summary

- Mid Term recap:
  - LAPPD project;
  - MC6 & MC7 simulation;

- Progress:
  - Theoretical prevision;
  - Simulation tricks;

- Results;

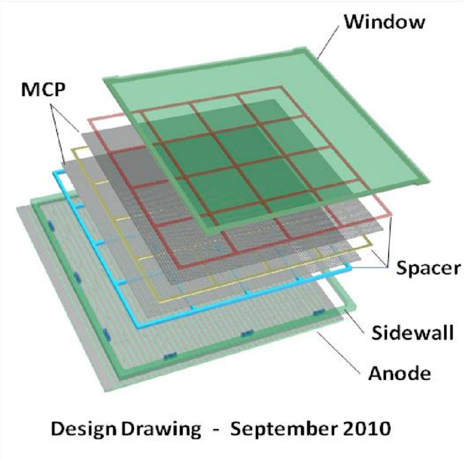
- Conclusions.

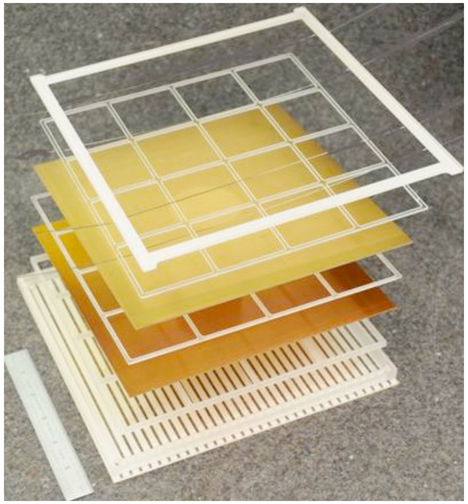
Large Area Picosend PhotoDetector:

Goal of the project is manufacturing <10 ps time resolution photodetector.

Key elements:

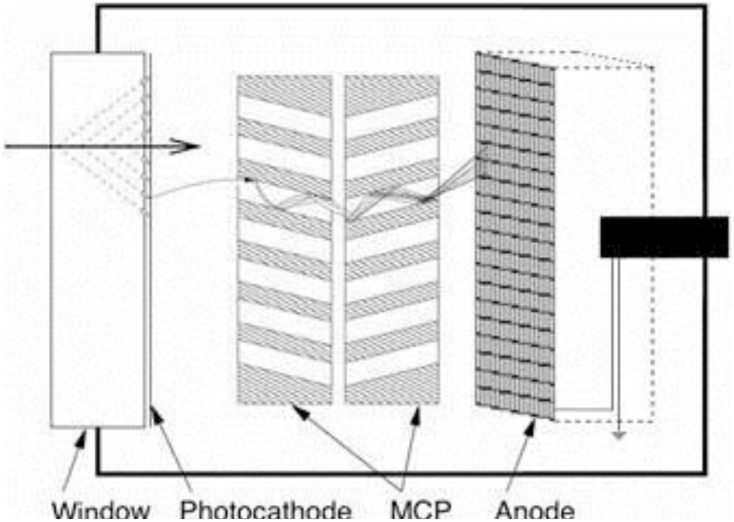
- Glass body, minimal feedthroughs;
- MCPs made using atomic layer deposition;
- Transmission line anode;
- Fast and economical front-end electronics;
- Large area, flat panel photocathode.





Criteria for sub-psec timing:

- Fast source: a psec source of many photons (e.g. Cherenkov light from a charged particle traversing radiator or the entrance window of a photodetector);
- psec-level pixel-size (10-20 µm pores in MCP);
- High gain: the gain has to be high enough that a single photon triggers, i.e: the first photon “in” determines the leading edge of the pulse and consequently the timing.



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My work:

- Time of Flight LAPPD will be tested at Fermilab Test Beam Facility so as to prove high time resolution:

- Having a precise knowledge of beam's shape, energy, composition through experimental setup is necessary in order to position detectors in the most convenient location.

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MC6 & MC7 simulations

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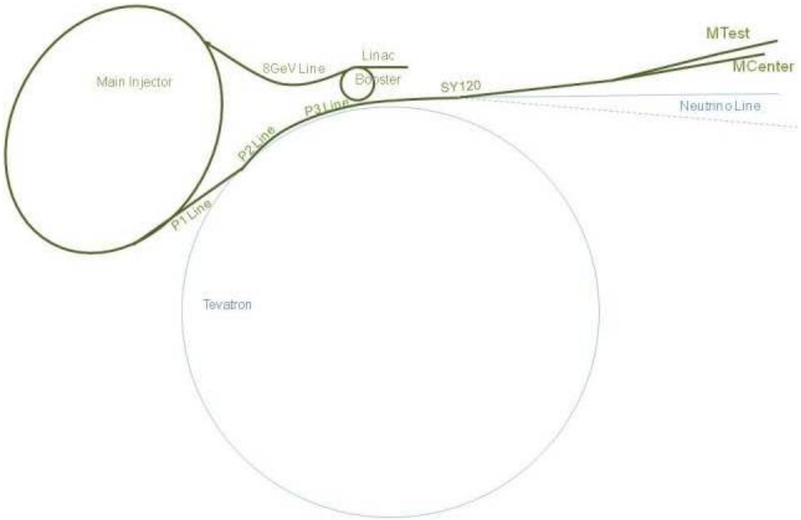
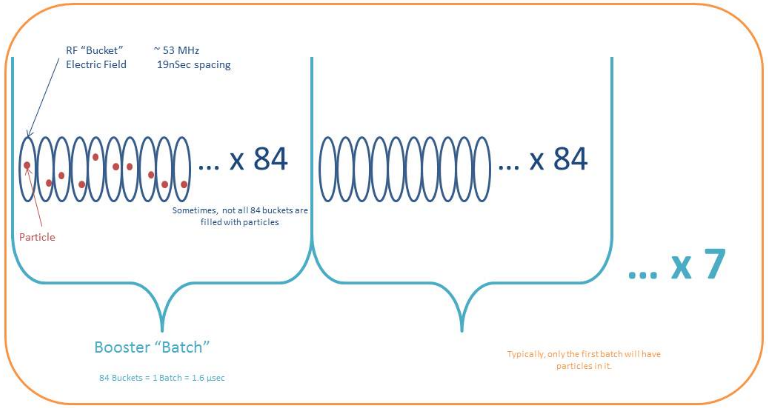
Where does FTBF receive beam from?

- Main Injector provides 120 GeV/c protons in 4.2 second-spills, with approximately 60 seconds of repetition rate.



- Spills are made up of batches: 7 batches covered 11,2 μs (size of Main Injector); every batch is composed by 84 RF buckets (size of booster).

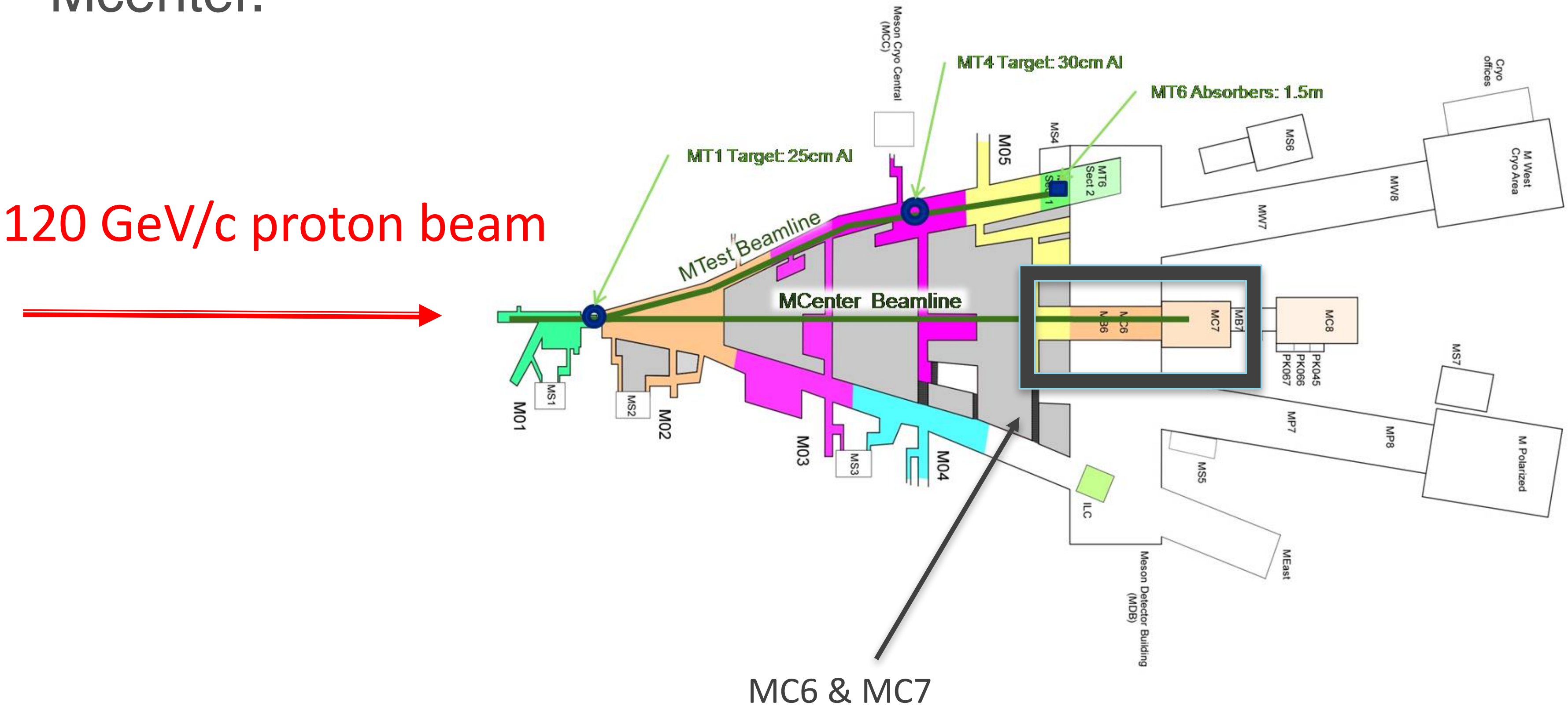


7 Batches = 1 MI Cycle = 11.2 microSec

- Only the first batch over 7 has particles.

Test Beam Facility

- The beam is transferred till M02 enclosure: it's then split in two beams so as to deliver particles to both MTest and Mcenter.



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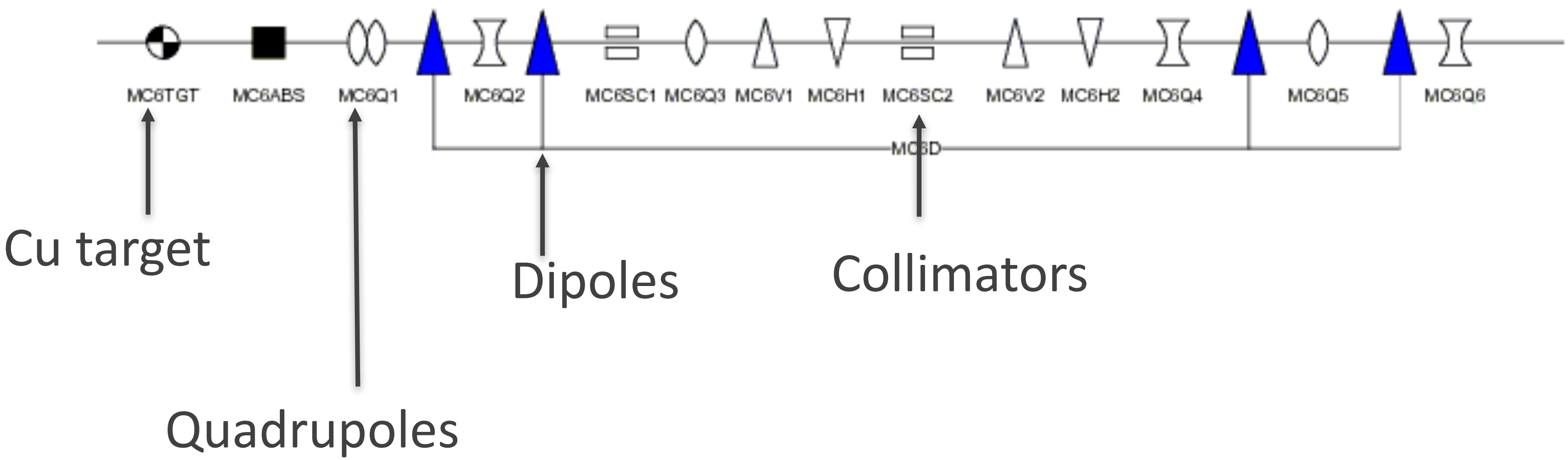
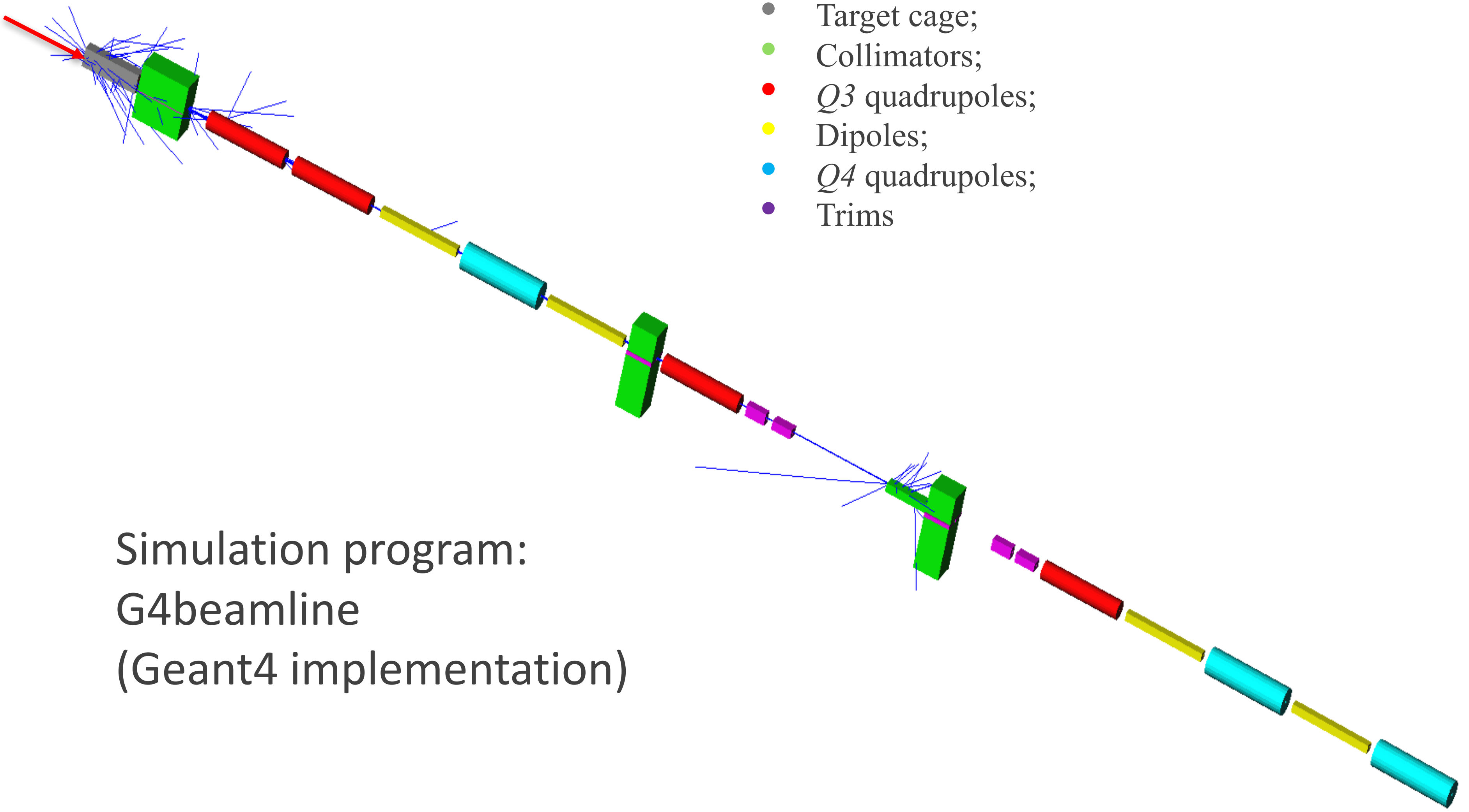
MC6 Structure

- 120 GeV/c protons hit the copper target: then they are guided (with interaction products) along the beam line.
- MC6 provides a low-intensity beam, of a chosen mean momentum, parallel to the floor.

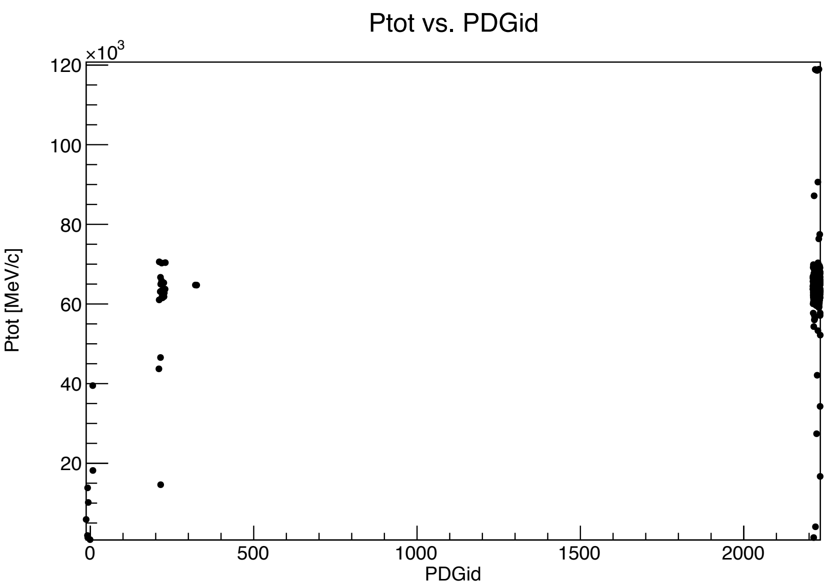


MC6 simulation

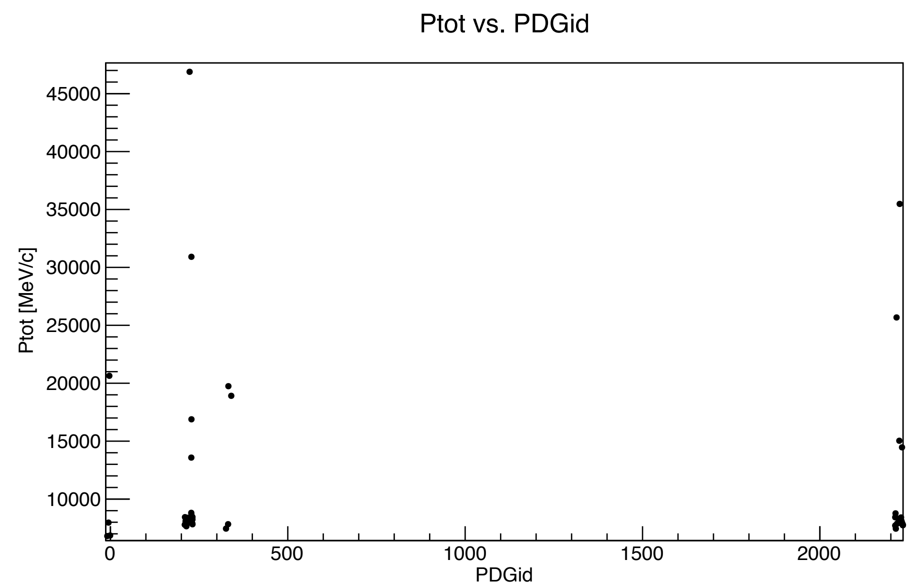


Simulation program:
G4beamline
(Geant4 implementation)

- Mean Momentum of particles is selected by:
  - Momentum Collimator: it physically stops above 90 GeV/c momentum particles (most of the beam);
  - Dipoles: they are all fed by the same power supply, hence they provide the same field, set for selecting mean momentum.

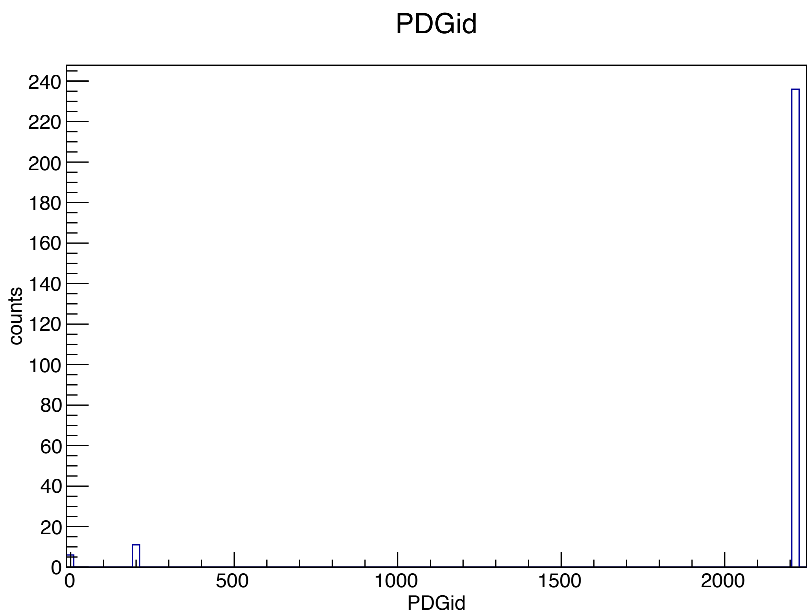


2 million-events simulation
64 GeV/c setup



2 million-events simulation
8 GeV/c setup

- Selecting momentum implies selecting species:



2 million-events simulation
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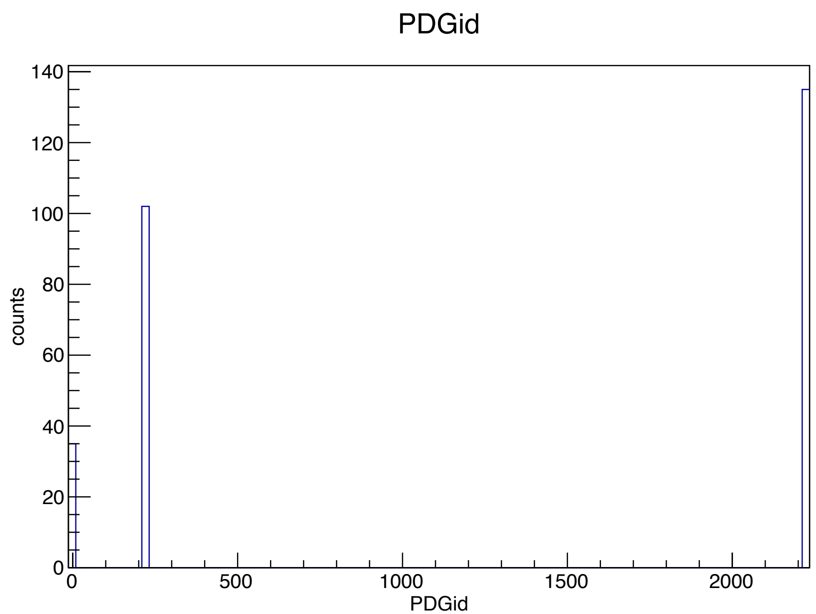


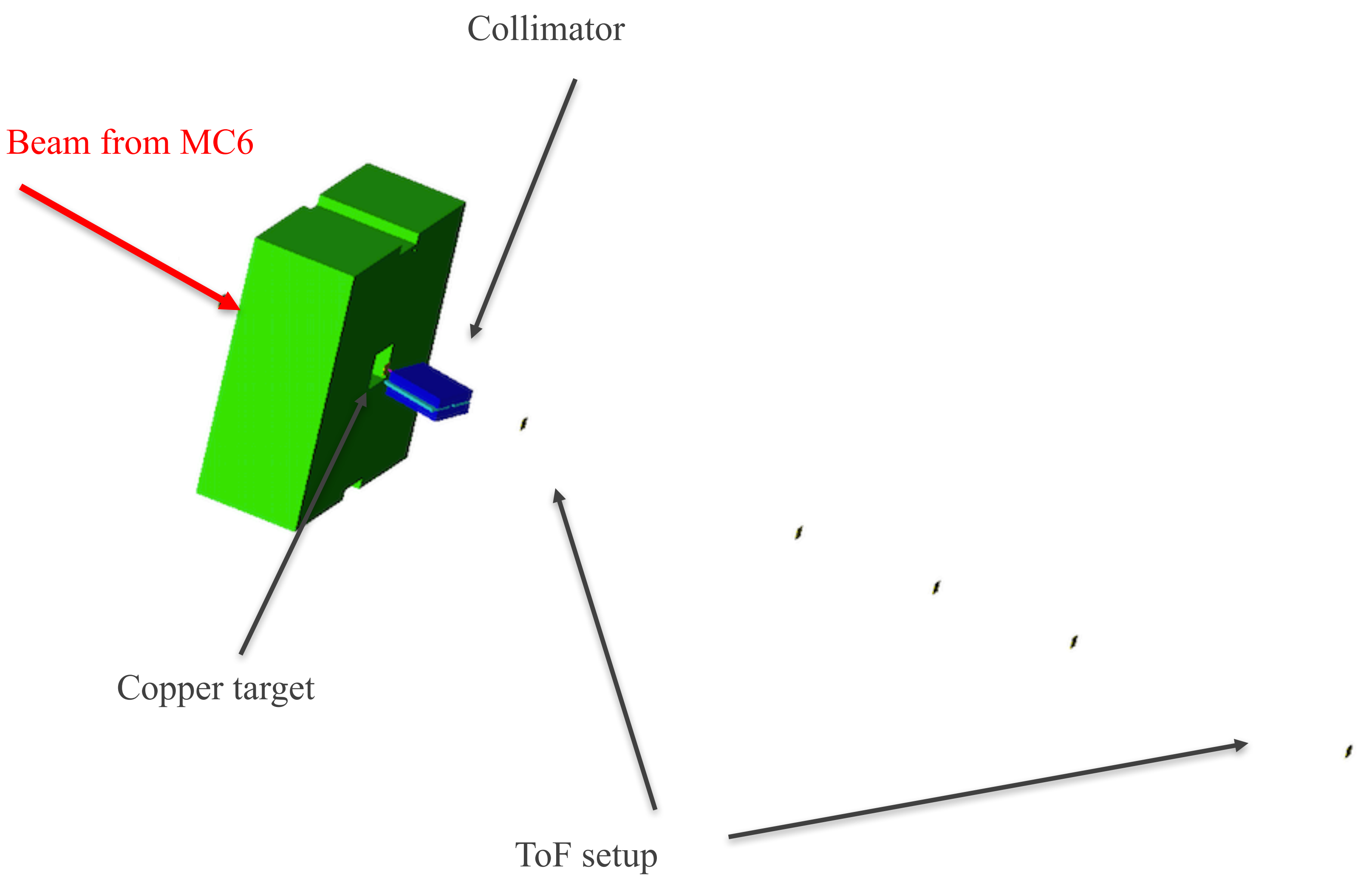
2 million-events simulation
8 GeV/c setup

Note: electron and gamma tracks are killed for reducing simulation running time

MC7 structure

- MC7 has calibrated instrumentation (counters, Cherenkov detectors, etc.) and can be customized for fitting experimental requirements;
- In this case, MC7 is made up of some detectors, a copper target (approximately 6 m downstream the last MC6 quad) and a collimator;
- LAPPD setup will be straight after the collimator, in the beam direction, so as to take advantage of the shielding effect.

MC7 simulation



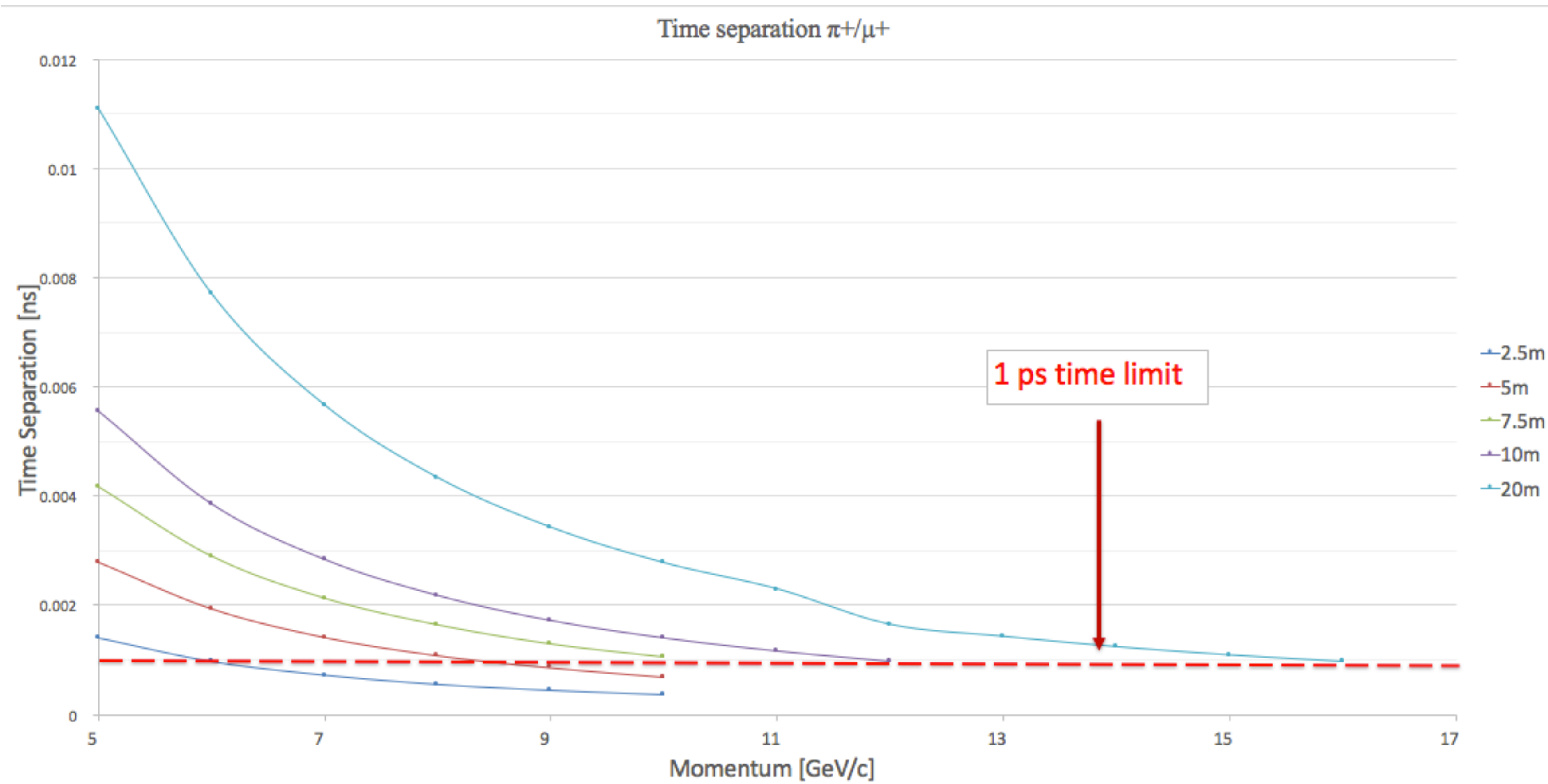
Theoretical previsions:

- Considering particles momentum and distance, it's possible to calculate the system capability of solving different species;

- Couples of interest are:
  - $\pi+$ / $\mu+$;
  - $\pi+$ / $K+$;
  - $\pi-$ / $e-$;

- Calculations have been executed considering particles travelling in vacuum along a straight path.

π+ / μ+ resolution plot:



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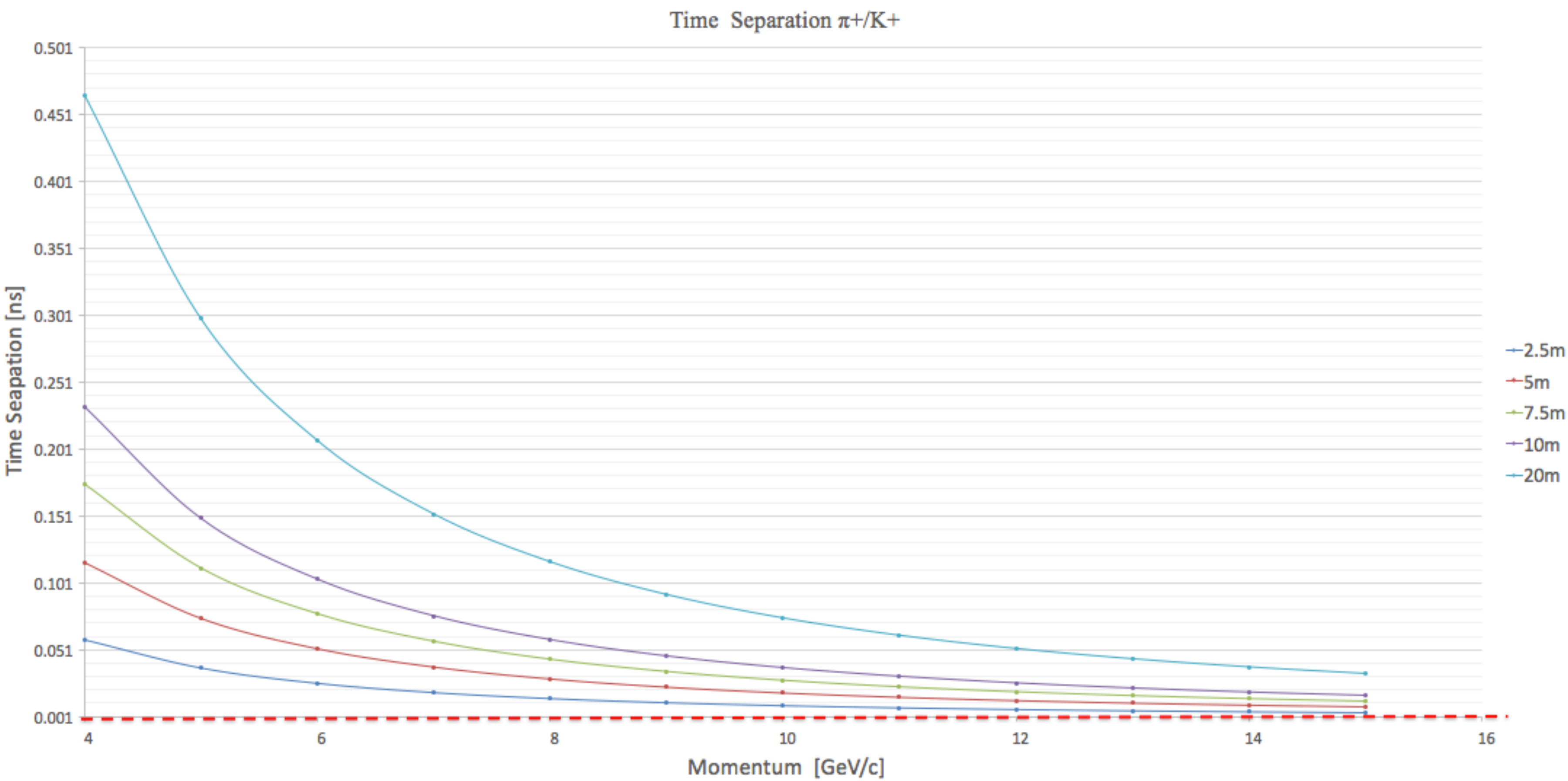
π+ / K+ resolution plot:



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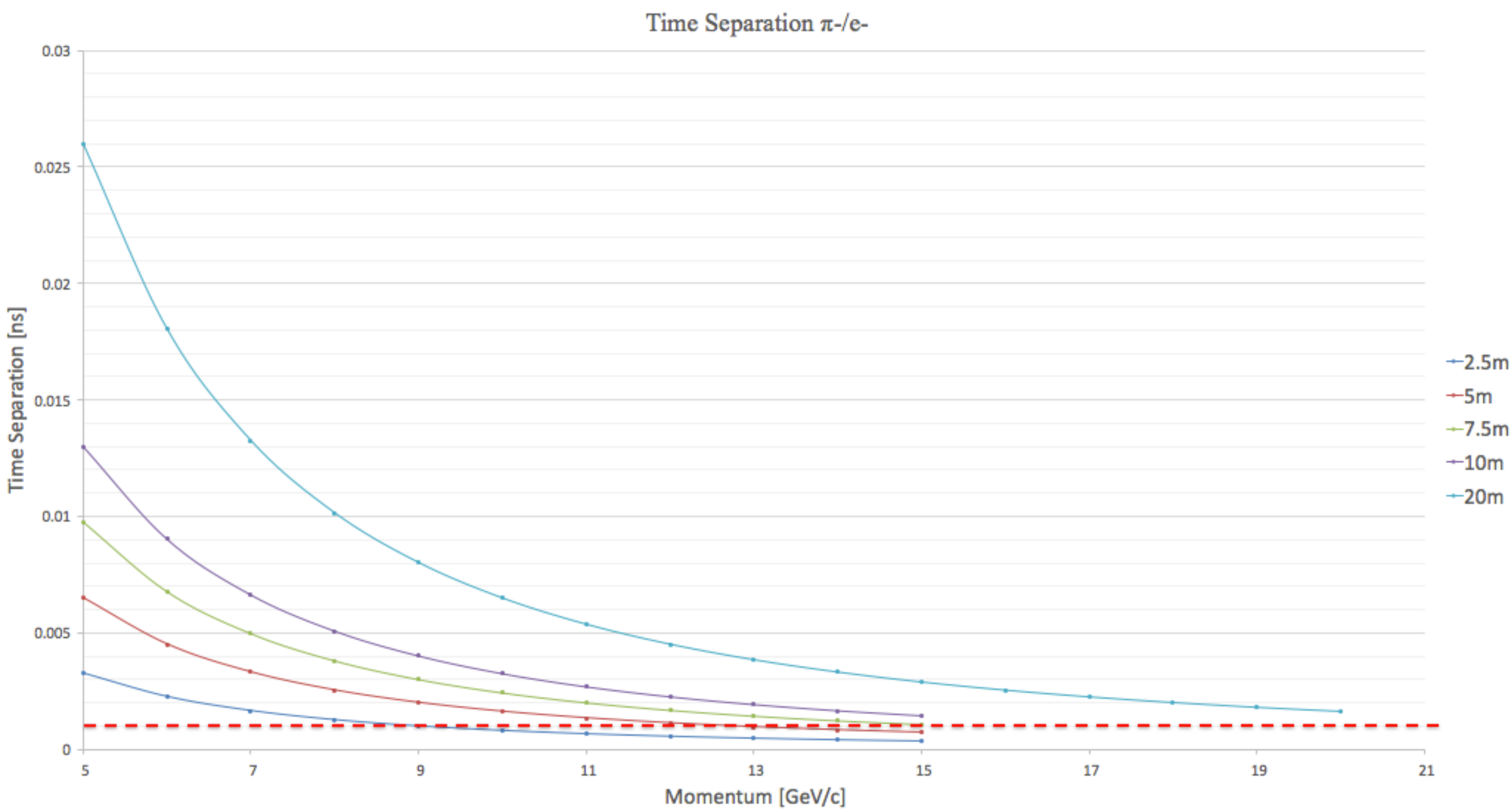
π- / e- resolution plot:

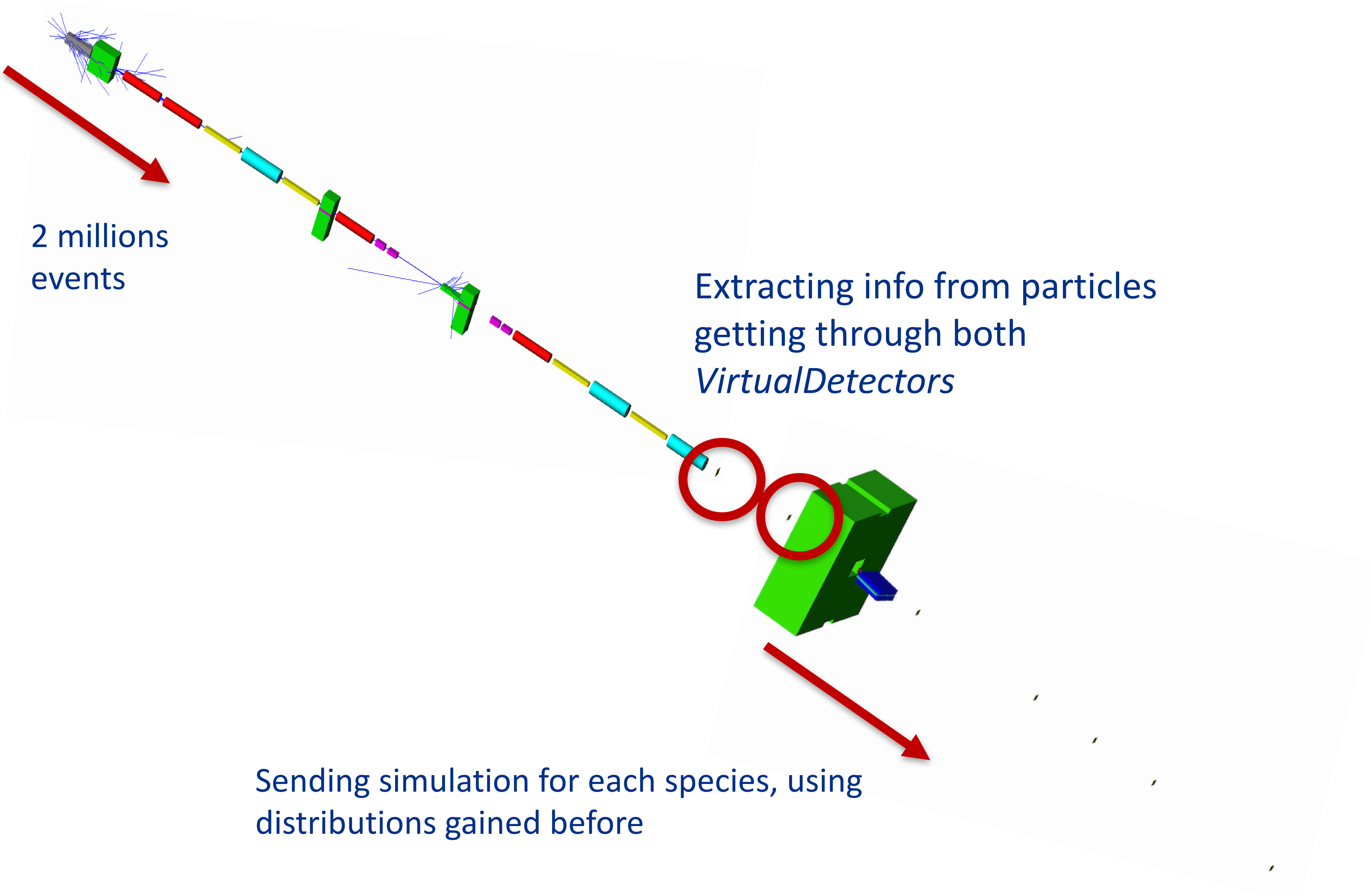


Simulation tricks:

- 2-million-event simulation requires 12 hours running;

- Simulating one spill (~ 500 millions particles) would take 3000 hours;

- For having statistically significant results, avoiding too long running time:
  - Consider spatial and momentum distribution of every species reaching the end of MC6 in 2-million-event simulation;
  - Proportionally calculate the number of events coming to MC7;
  - Run simulations equivalent to 500-million-event one.



2 millions events

Extracting info from particles getting through both *VirtualDetectors*

Sending simulation for each species, using distributions gained before

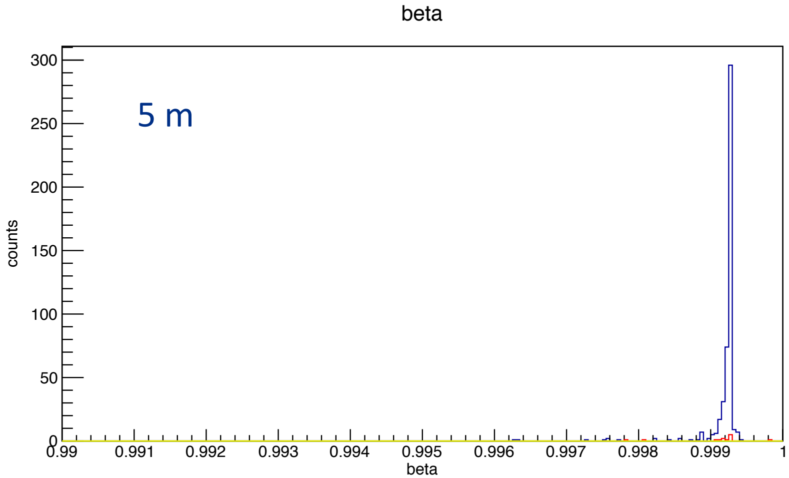
Results:

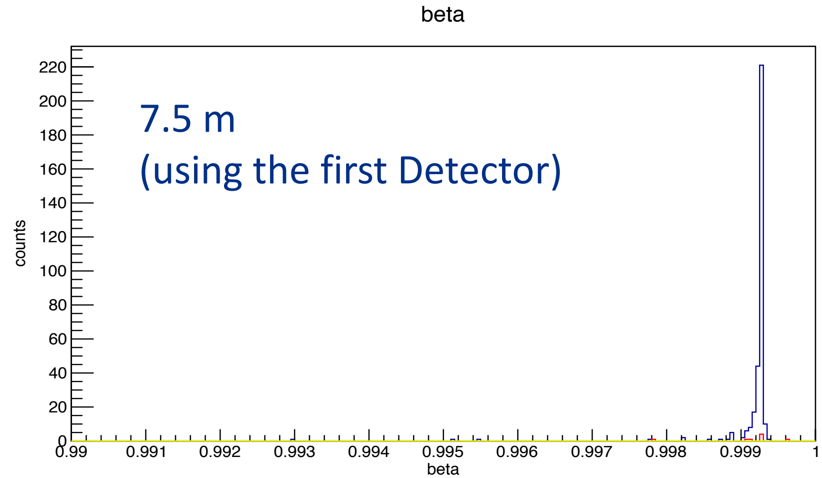
- Analysis code takes as input two selected Time-of-Flight *VirtualDetectors* and considers particles hitting both of them;

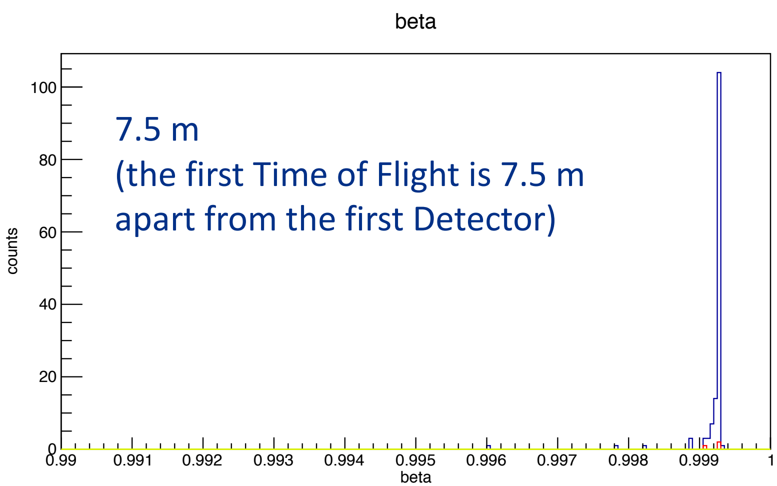
- It calculates β value using Time of Flight and position of the hit;

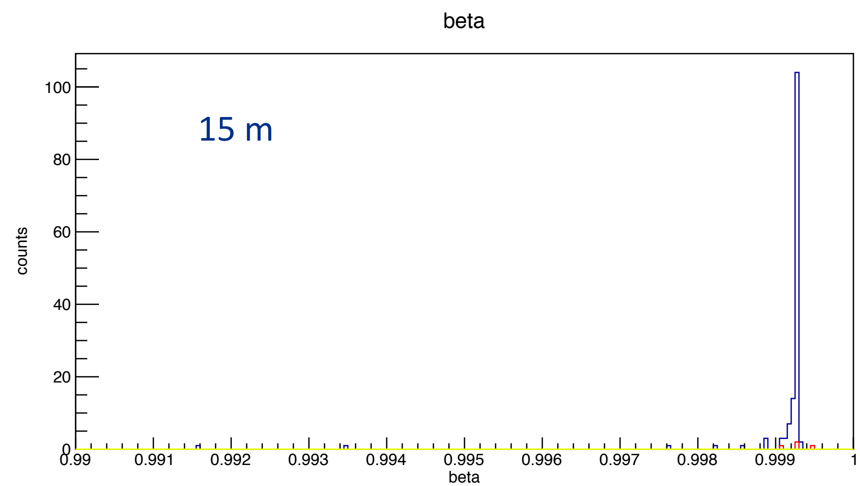
- It calculates error **Δ**β propagating errors on measurements:
  - 1 ps of time resolution;
  - 7 µm on transversal positions;
  - 8 mm on longitudinal position (thickness of the Cherenkov glass).

8 GeV/c setup results:

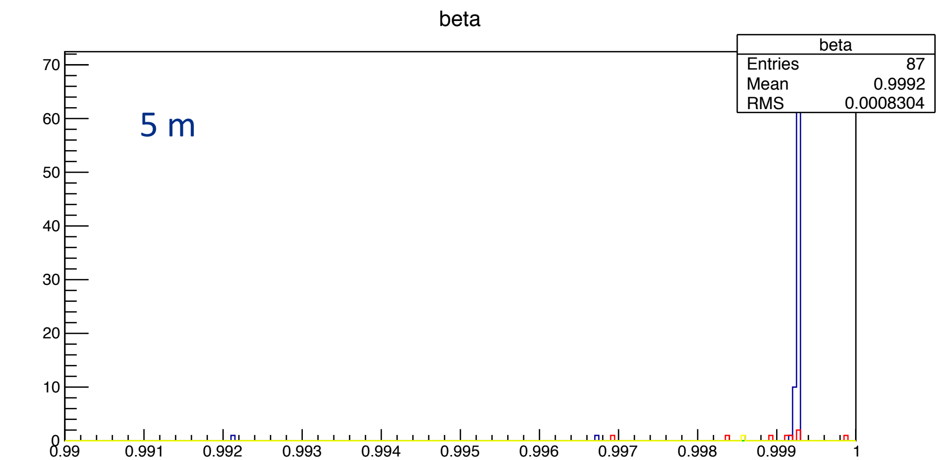


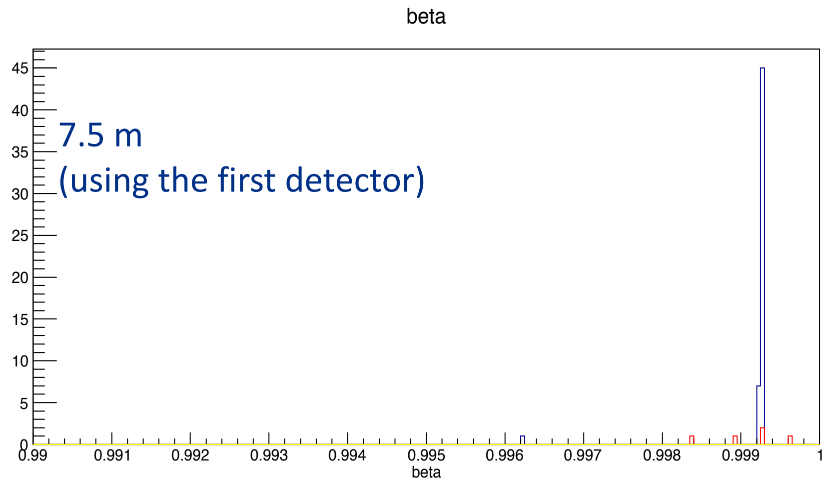


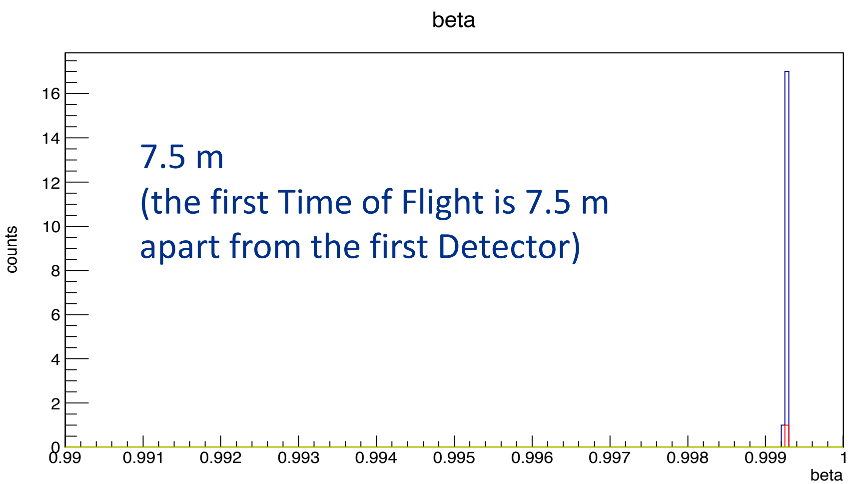


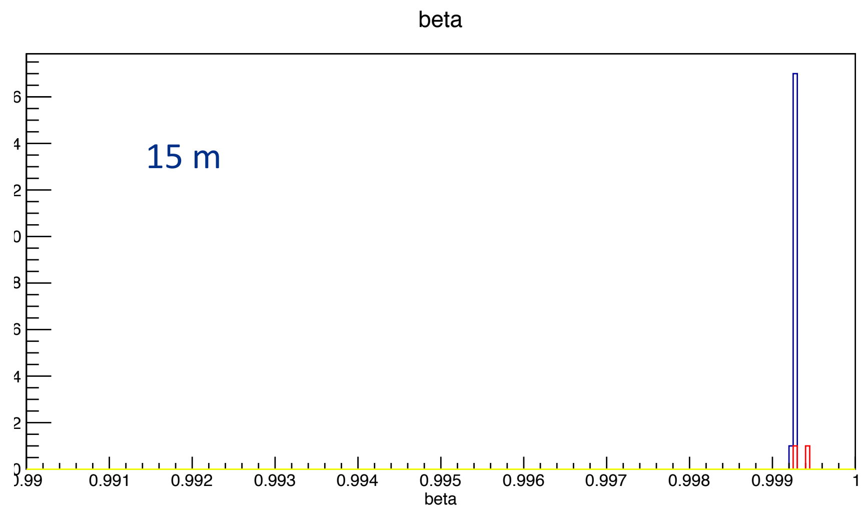


16 GeV/c setup results:









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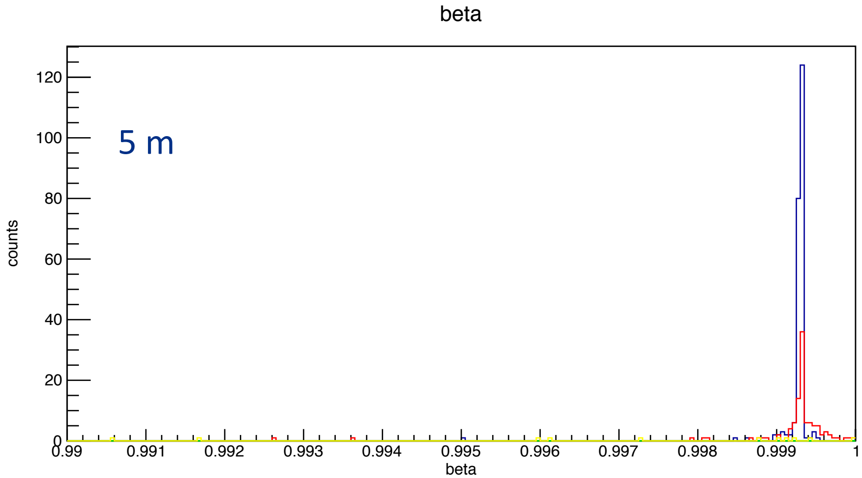
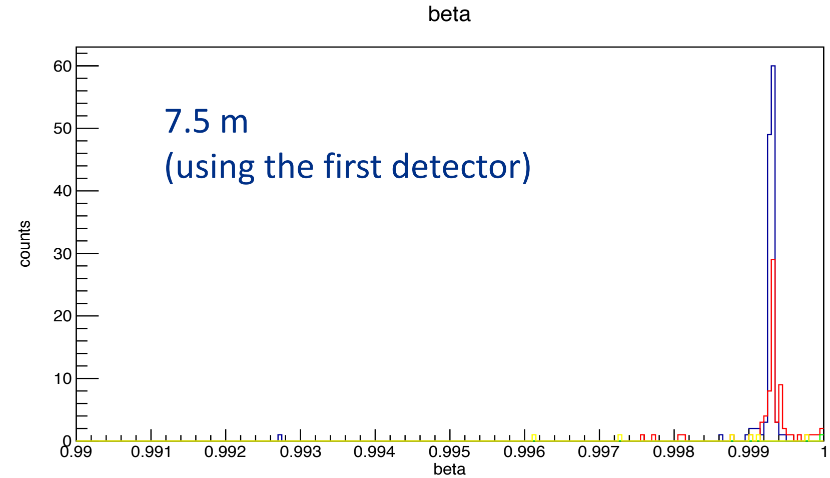
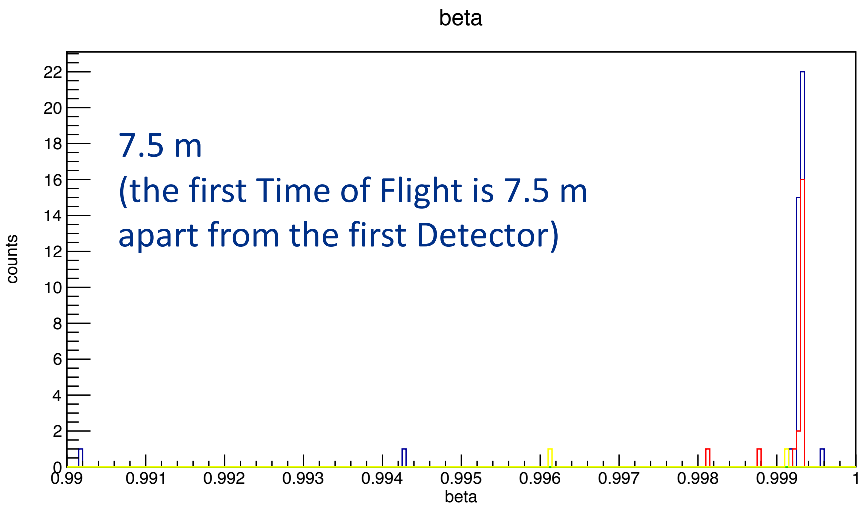
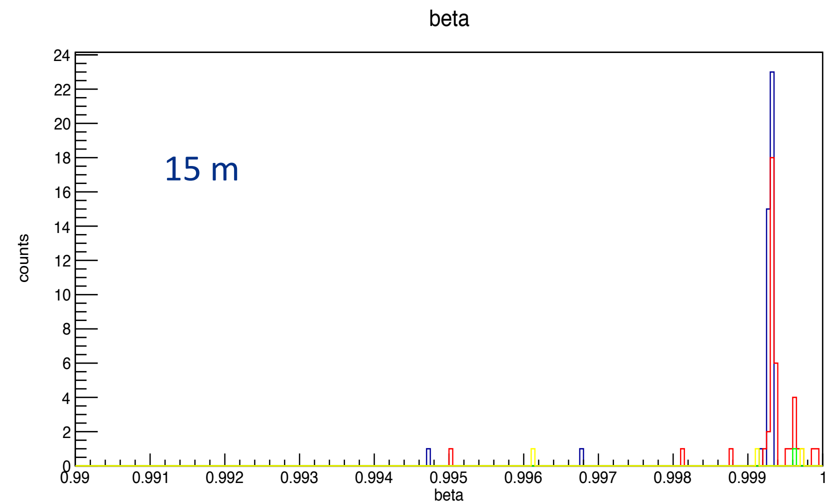
64 GeV/c setup results:









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Conclusions:

- MCenter provides a large momentum range and the possibility of having a low intensity beam;
- Choosing a low momentum setup, it’s possible to have a quite “clean” muon beam;
- Simulation results are confirmed by real historic data: it’s precise and reliable;
- The farer detectors are, the more precise measurements are, and the more ”clean” the beam is.

Conclusions:

- LAPPD Time-of-Flight setup will consist of three detectors;
- Since the beam composition and properties, and MC7 structure, the best placement will be 7.5 m of distance between detectors;
- Hence, the following configurations will be available:
  – 7.5 m, using detectors 1 & 2;
  – 15 m, using detectors 1 & 3;
  – 7.5 m, using detectors 2 & 3.

Conclusion:
What I gave Fermilab:

- Database of MC6 & MC7 outlines;

- Simulation of beam lines.

Conclusion:
What Fermilab gave me:

- New knowledge about particle accelerators and transfer systems;
- Taste of working in a real scientific environment;
- **PATIENCE.**

Many thanks for your attention