

Search for Magnetic Monopoles With the NOvA Detector



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On Behalf of the NOvA Collaboration



1. The NOvA Far Detector

The NOvA far detector, located at Ash River, MN, is the largest scintillator detector in the world: 15.6m x 15.6m x 66.9m.

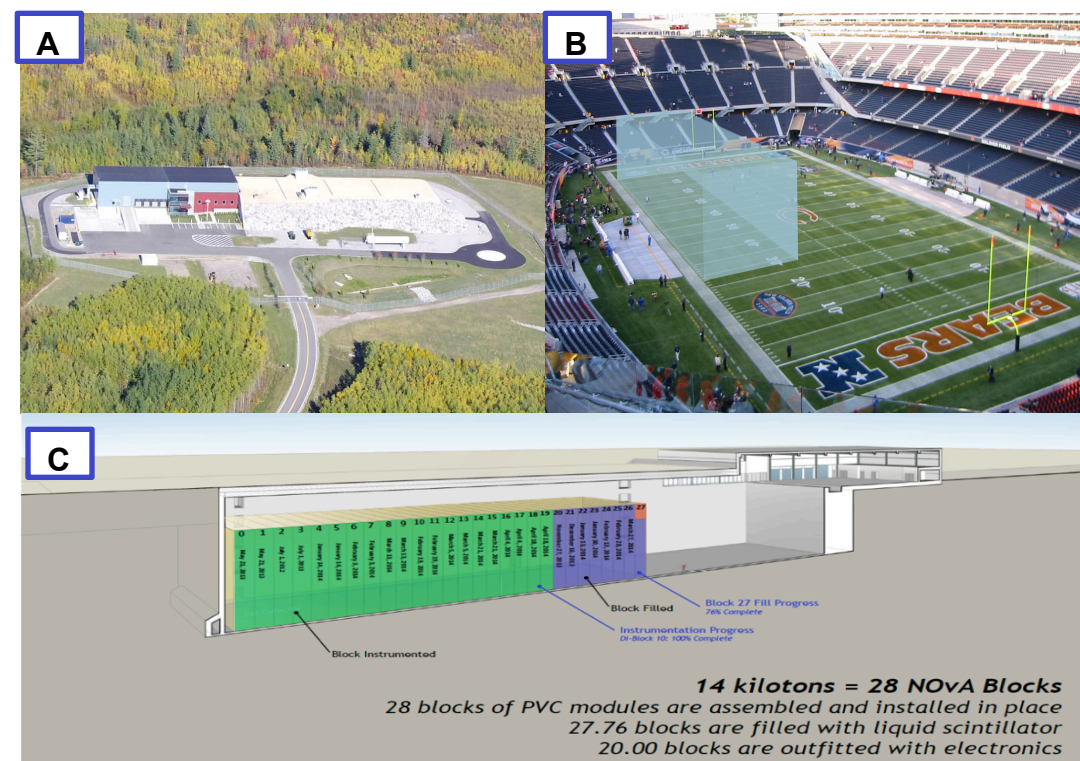


Figure 1

(A) The detector site at Ash River. (B) A scale of the entire effective region of the detector compared to a football stadium. (C) Current status of detector construction.

Each cell is 3.9 cm x 6.0 cm x 15.6 m large and filled with scintillator oil. The trajectory of a charged particle is determined as it passes through adjacent horizontal and vertical planes, as shown in the layout Figure 2.

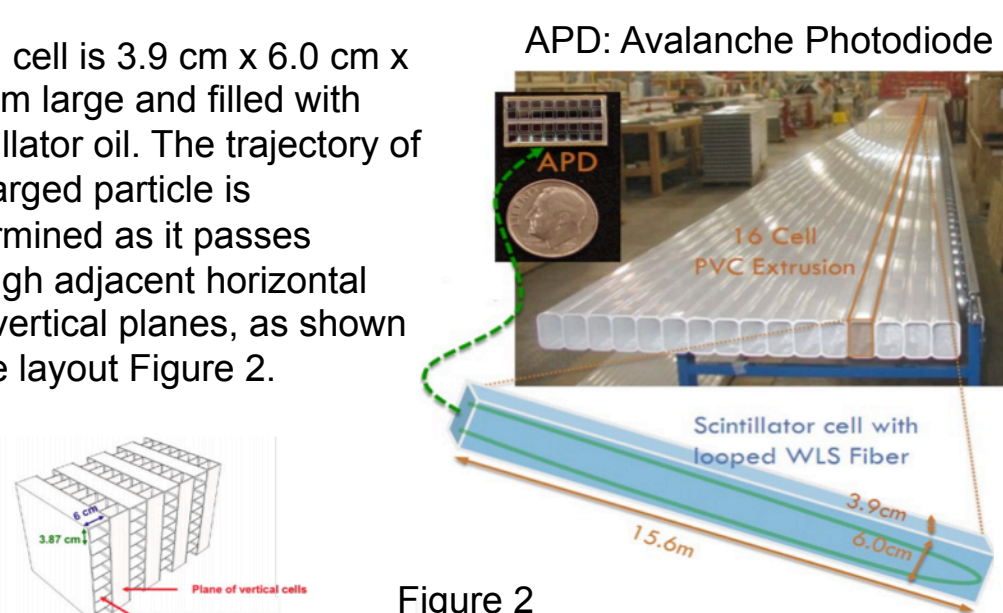


Figure 2

3. Fast Magnetic Monopole Events Triggering

We have developed two data-driven triggers to record “potential” monopole events within a certain time window. Fast monopoles tend to be heavily ionizing and the corresponding hits will be contained in relatively short time window, the trigger decision is made based on the information of the hits which are clustered in a “slice”.

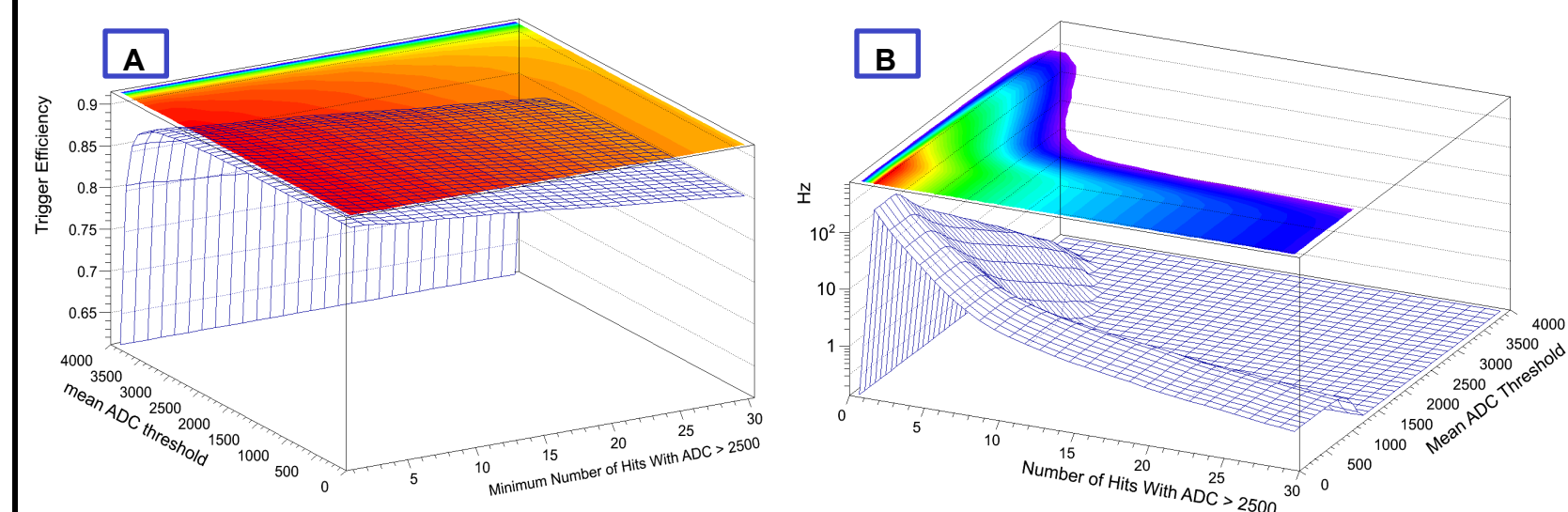


Figure 7: The trigger efficiency (A) and the trigger rate (B) as a function of minimum number of high ADC hits and minimum ADC per hit in the slice.

4. Slow Magnetic Monopole Events Triggering

The slow monopole trigger picks possible combination of entry and exit hits which are close to the boundary of the detector. From the information of the “entry” and the “exit”, we can determine whether a hit is on the “possible monopole track”. Once a possible combination obtains enough hits on track in unit length, the corresponding time of transit is found.

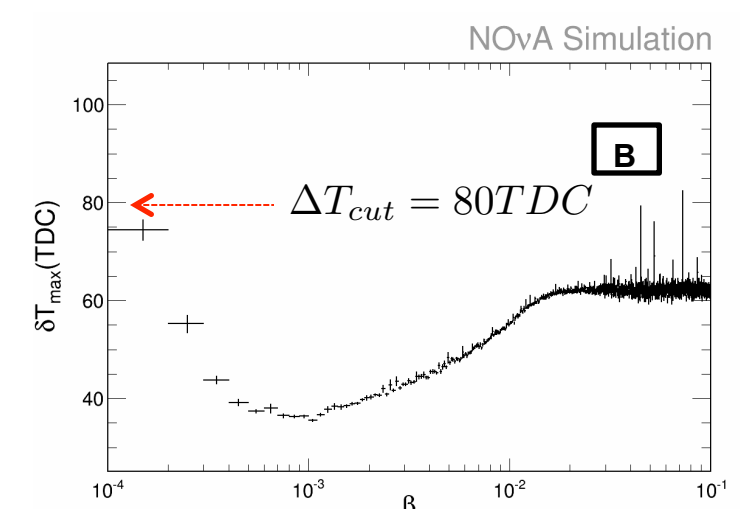
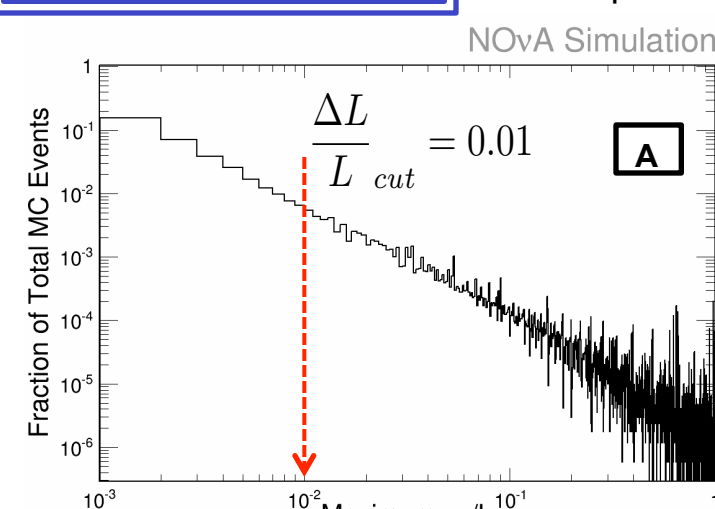
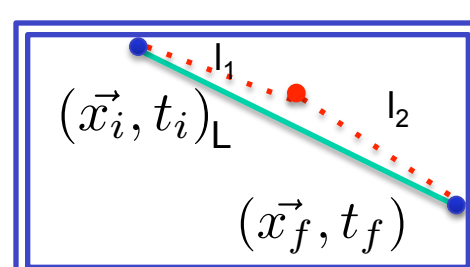


Figure 8: (A) The maximum additional length of true hits in an MC event; (B) The maximum time difference (1TDC = 15.6 ns) of the expected time calculated from entry(exit) hit in an MC event.

5. Projected Sensitivities for the full NOvA Far Detector Exposure

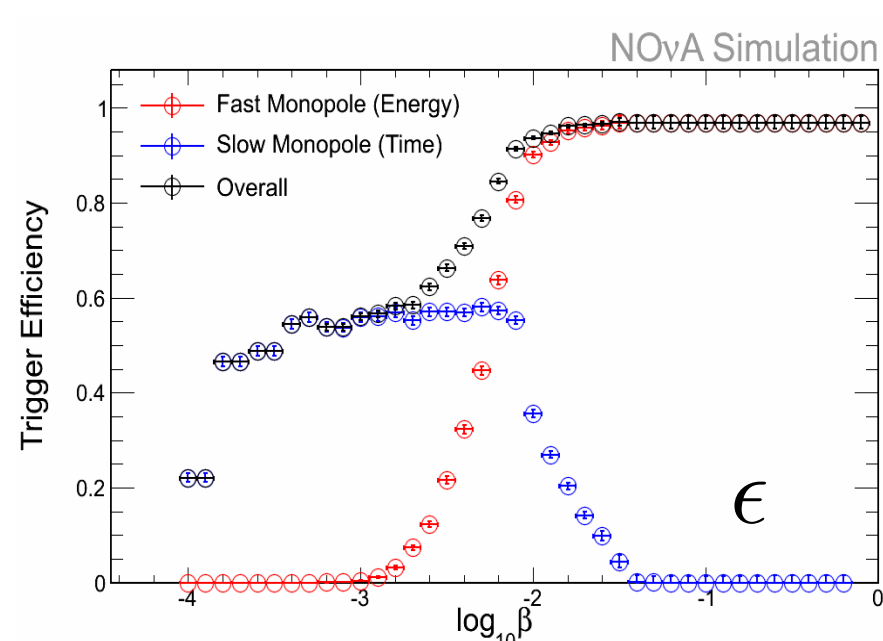


Figure 9: Trigger efficiency as a function of the velocity of isotropic MC monopoles.

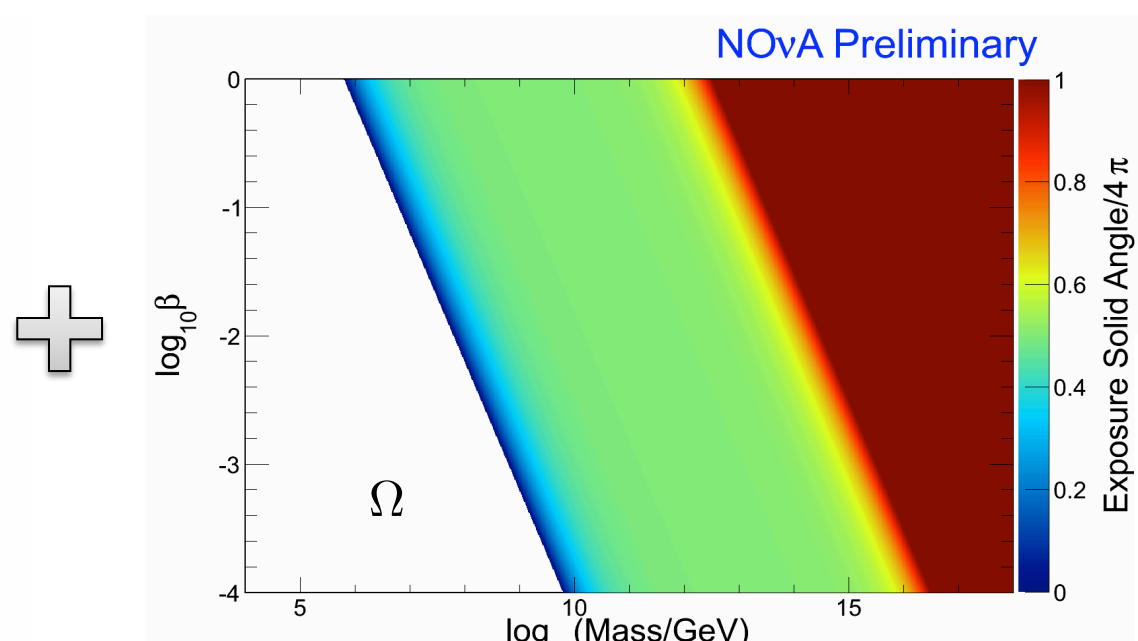


Figure 10: Angular acceptance plot based on energy loss calculation of monopoles through the atmosphere and the earth.

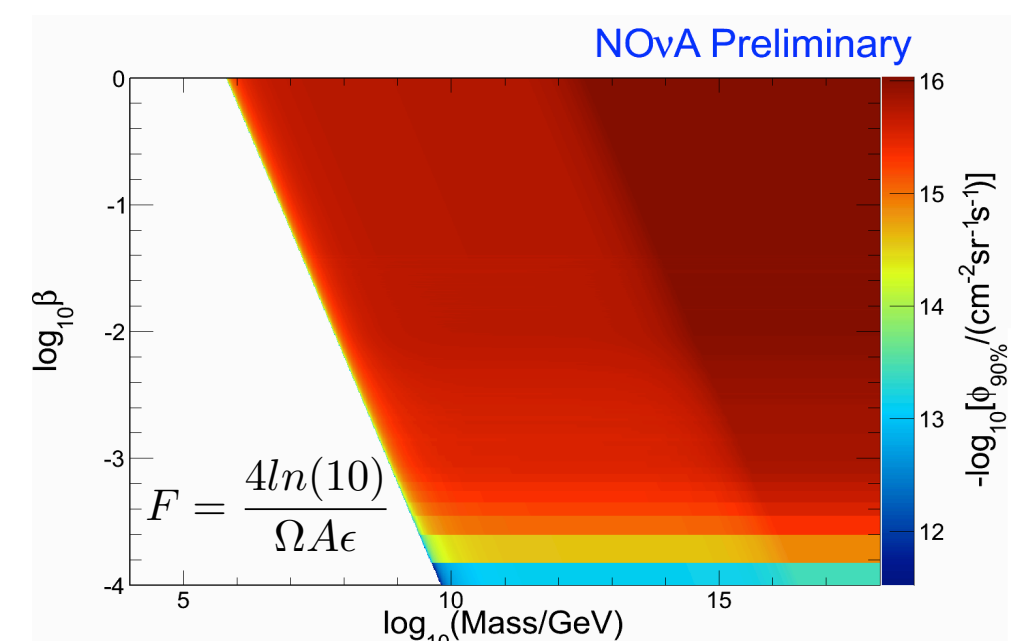


Figure 11: Assuming a background-free analysis and negligible signal cut losses, the 90% C.L. upper flux limit of 6 years running can be calculated from figure 9 and 10.

2. Magnetic Monopoles Simulation And Searching Strategy

Due to the surface location of the NOvA detector, we have a larger angular acceptance for low kinetic energy cosmic magnetic monopoles compared to the IceCube^[1] and MACRO^[3] detectors which are underground. The area of NOvA detector is greater than the SLIM^[2] detector. Figure 3 briefly shows the sensitivity of previous leading experiments in searching for cosmic magnetic monopoles.

Reference:

- [1] R. Abbasi et al. (IceCube Collaboration), Phys. Rev. D 87 022001 (2013)
- [2] S. Balestra et al., Eur.Phys.J.C55:57-63 (2008)
- [3] M. Ambrosio et al., Eur. Phys. J. C 25, 511–522 (2002)

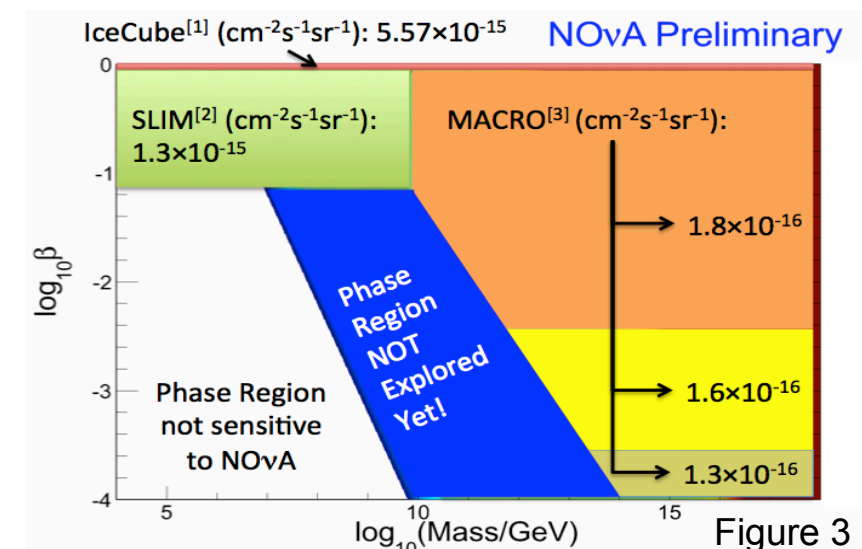


Figure 3

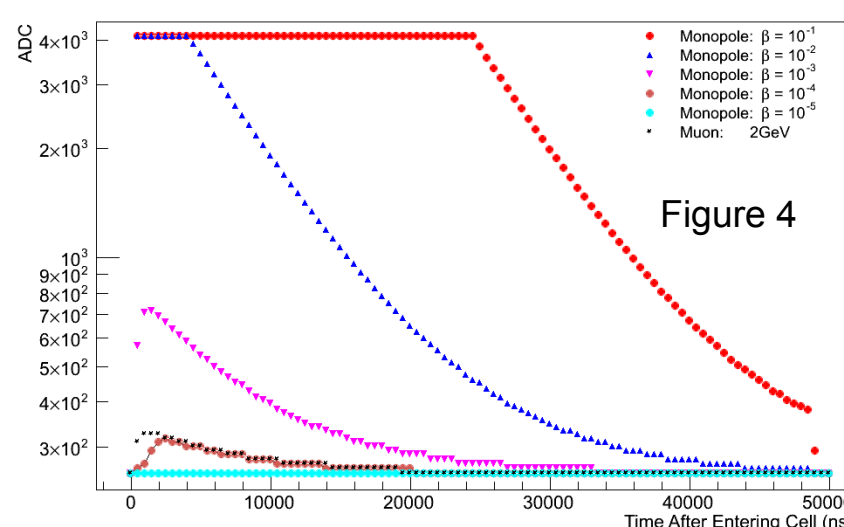


Figure 4

Figure 4 shows the detector response simulation of a monopole with different velocities travelling through a cell in the detector along the same trajectory. A minimum ionizing 2GeV muon with same trajectory is shown as a scale. The total energy deposited in a cell is represented by ADC counts, which are in the range [0,4095]. Fast ($\beta > 10^{-2}$) magnetic monopoles produce a lot of saturated (reaching maximum ADC read out) hits along a track since they are heavily ionizing. For slow ($\beta < 10^{-2}$) magnetic monopoles, we are able to distinguish them from other cosmic rays by their long transit times.

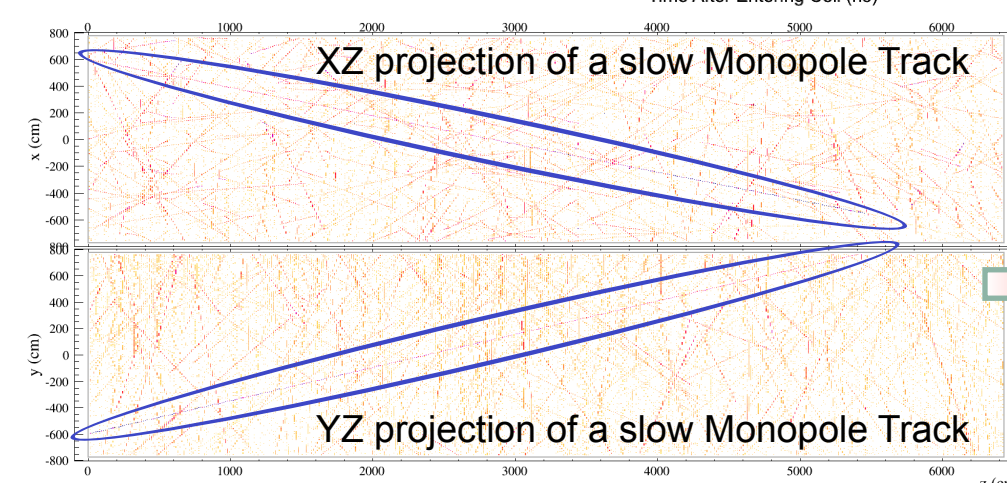


Figure 5

Figure 5 is the event display of a simulated magnetic monopole with mass = 10^{16} GeV/c² and $\beta = 10^{-3}$. This monopole track has been successfully picked out from the large cosmic ray and noise background, and reconstructed with 2D information from both XZ and YZ views in Figure 6.

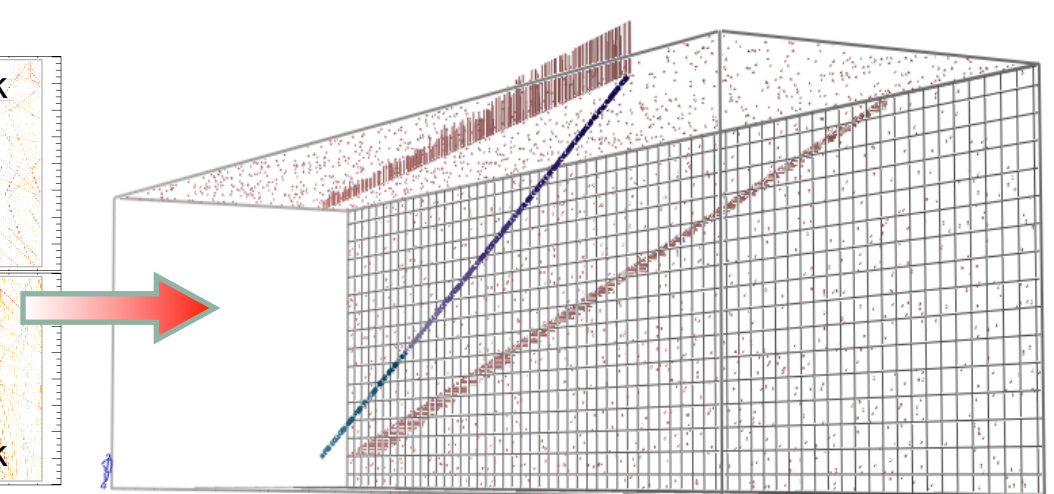


Figure 6