Comments on Alignment of Detectors in Roman Pots

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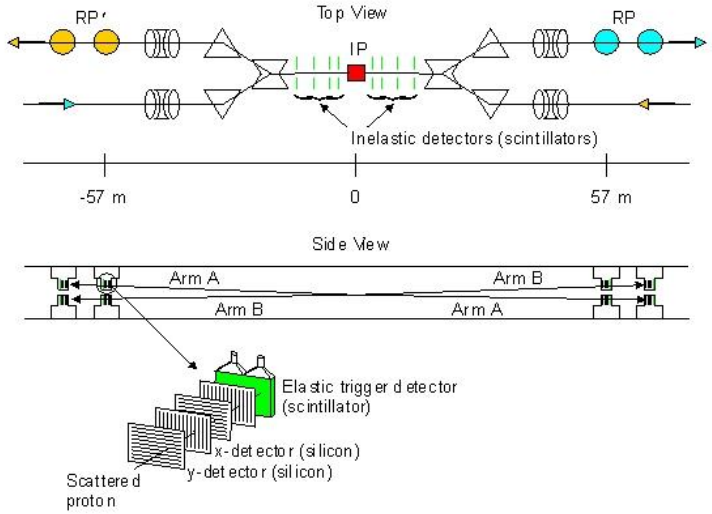
1. Brief description of the setups – PP2PP experiment and STAR experiment
2. Lessons learned: What is important, but keep in mind the differences between setups at RHIC and EIC

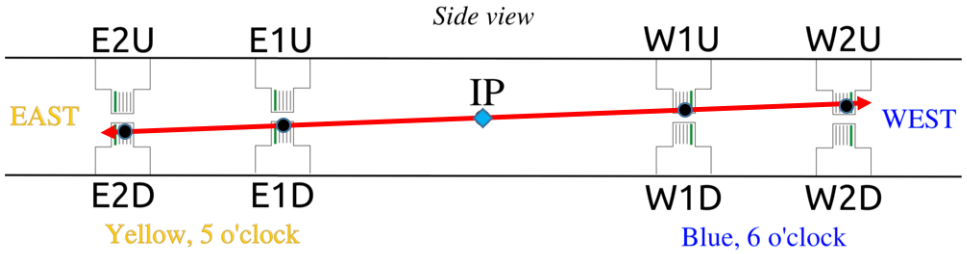
RHIC: Heavy Ion and Polarized Proton – Proton Collider

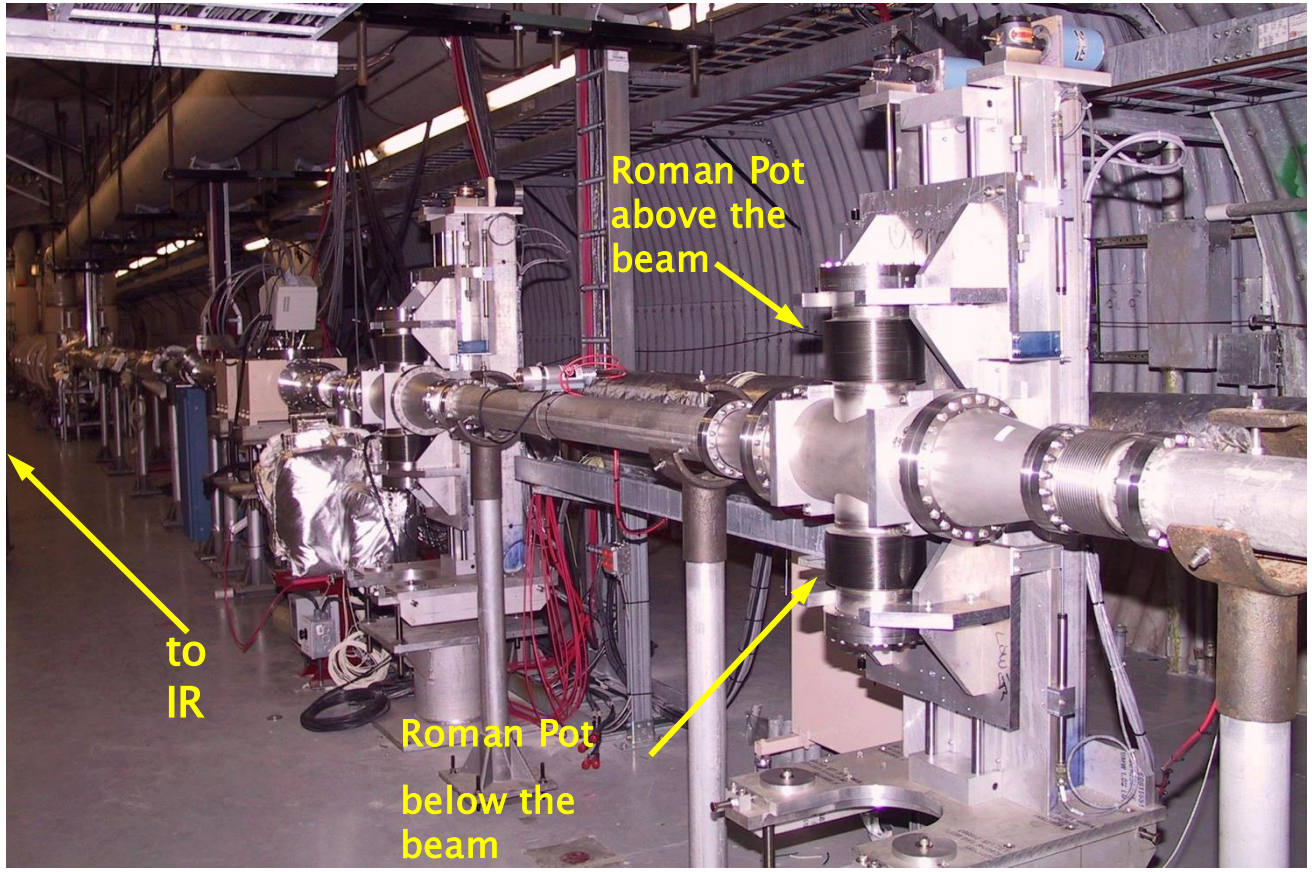
One of the few slides which shows that there were initially five experiments at RHIC

The Setup

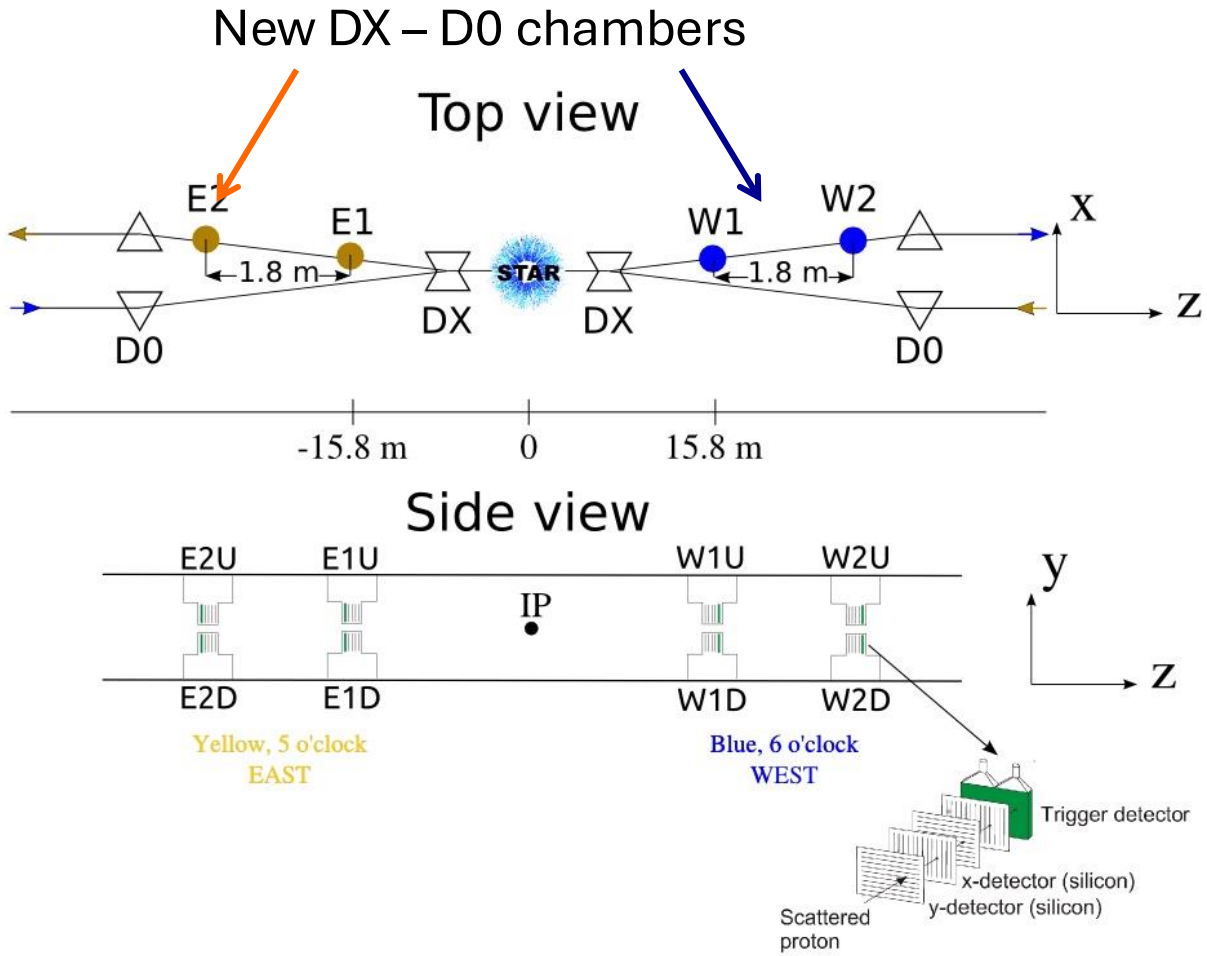


$$\vec{p}_1 = -\vec{p}_2 \Rightarrow (\Theta_x^1, \Theta_y^1) = (-\Theta_x^2, -\Theta_y^2)$$





Layout of the setup at STAR in 2015 and beyond



Coordinate systems

1. Accelerator coordinate system: magnets (magnetic field)

2. Detector packages in RPs are surveyed during the installation in principle with respect to #1

3. Central detector also surveyed with respect to #1, but that precision may not be very high.

4. All survey results (#2, #3) need to be corrected using data taken during physics runs.

Survey of the detector package

A detector package being surveyed in the lab (tabletop setup); Centering pin and reference point or point (0,0) on the detector package shown by arrow (top-left corner); Two tooling balls shown by circles (top and bottom right corners). Those tooling balls are the external reference used for the survey in the tunnel.

Steps of the alignment

Survey feasibility was part of the design of the detector package.

1. In the lab:
   - Alignment of the detector planes during assembly
   - Alignment/survey with respect to the targets that can be surveyed after detector package is installed in the RPs.
2. In the tunnel:
   - Survey alignment: Survey in the accelerator coordinate system with respects to the targets in the tunnel
   - Calibration of the motion and position readout (LVDTs)
3. Corrections to the survey alignment were obtained using elastic scattering data. A powerful constraint of collinearity the elastic scattering was used.

Relative alignment of the detector planes

- By design the detector package was designed with alignment pins to keep the relative alignment of the four detector planes constant.
- Each Si plane had a survey mark, which determined (x0, y0) position of the first strip. The remaining strips were very well aligned because of the geometry of the mask used to produce the sensos.
- That survey mark was used to align planes with respect to each other during assembly of the detector package.

Survey of the detector package

A detector package being surveyed in the lab (tabletop setup); Centering pin and reference point or point (0,0) on the detector package shown by arrow (top-left corner); Two tooling balls shown by circles (top and bottom right corners). Those tooling balls are the external reference used for the survey in the tunnel.

Survey in the tunnel and corrections to the alignment.

- After detector package installation in the tunnel only the two tooling balls were visible.
- Those tooling balls were surveyed in the tunnel as function of the position measured by the LVDT. Thus the position of the first strip (x0,y0) and the bottom of the RP as function of the LVDT readout was obtained.
- Those positions were used during the data taking to keep operations safe.
- In the final step elastic scattering events were used to obtain corrections to the mentioned above survey alignment. They were of the order of 20-30 microns.
- Elastic scattering was solved in that coordinate system.

Final comments

- The major lesson is that the alignment needs to be taken into account at the very beginning of the design of the detector package and sensors.
- The crucial thing is to determine the beam position and angle at the detection point. This was not controlled very well at RHIC since the Beam Position Monitors (BPMs) were in stalled in the cold mass of the magnets and their offsets (position and electronic) were not well known.
- Keep in mind that accelerator needs a relative alignment of the magnets, which is achieved through so called beam-based alignment.
- The experiment needs the beam position and angle in the experiment's coordinate system. This requirement must be part of the accelerator design.

For all this and other mechanical design needs, one dedicated mechanical engineer and a designer are needed.