Position determination of fragile objects in nuclear physics experiments

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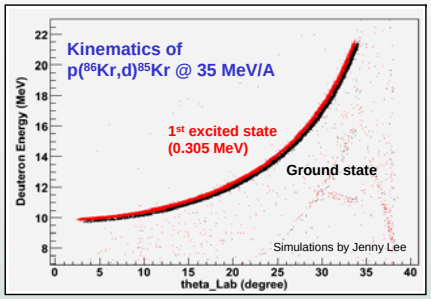
Inverse kinematics transfer reaction is used to study the structure of exotic nuclei. Sub-millimeter accuracy is required in our position measurements.

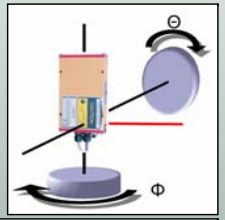
Requirement for position measurements

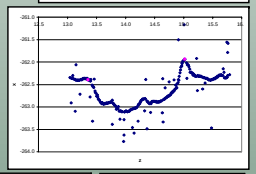
- Must be Non-Contact
  - Mechanical measurements may alter the configuration of our setup
  - It may also damage our detectors and target foils
- Accurate (sub-millimeter) position measurements
  - needed to resolve nucleus of different excited states

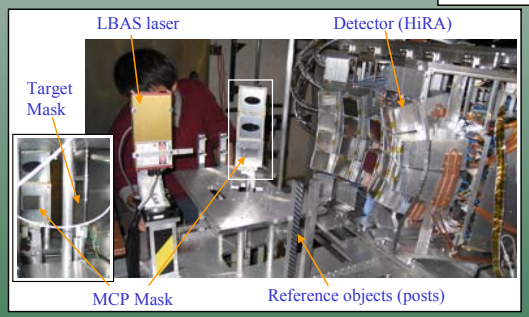


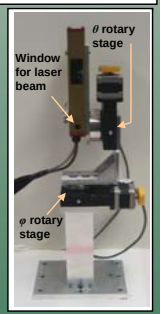
Laser Based Alignment System (LBAS)

- Small and portable, can be used inside an experimental chamber
- Measure (r, θ, φ) of a point in space
  - Resolution in r : 45.6 μm
  - Angular Resolution: less than 0.006°
- Misalignment of the rotation axes
  - The offset is corrected at the early stage of data analysis
- Limited Range: 25.4 cm – 40.6 cm
  - Measurements are made at different laser positions
  - Measure the same reference objects for each of the laser positions to determine their relative positions
- Transformation between laser positions
  - Combination of translations and rotations
  - Parameters (Euler angles and rotation vector) are determined from fitting
- Match all measurements into a global coordinate system

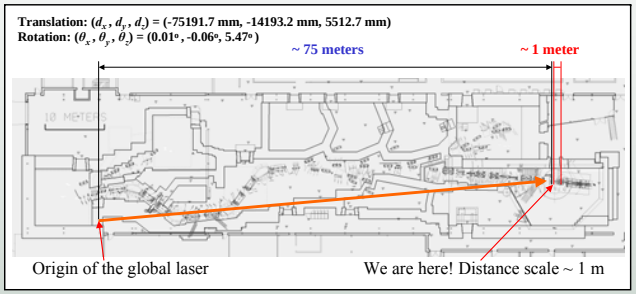


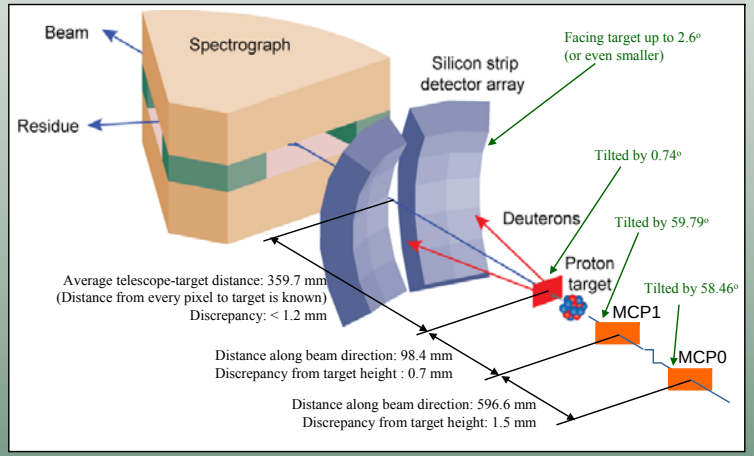






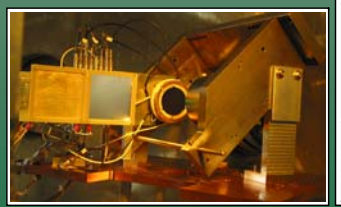
Experimental Setup

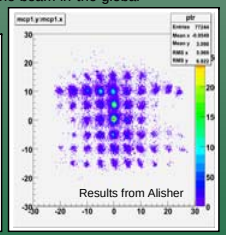




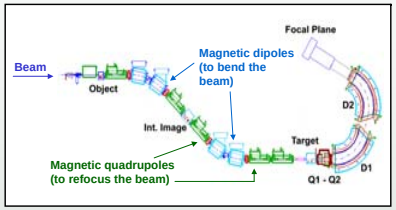
Micro-Channel Plate Detectors (MCP)

- Provide position and timing information of an ion traversing the target
- Especially important when the beam size is large (~2 cm in diameter for radioactive beam such as ^{56}Ni)
- The beam position can be calibrated using a MCP mask
- By measuring the MCP mask, the position of the beam in the global coordinates is determined





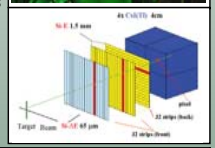
S800 Spectrometer



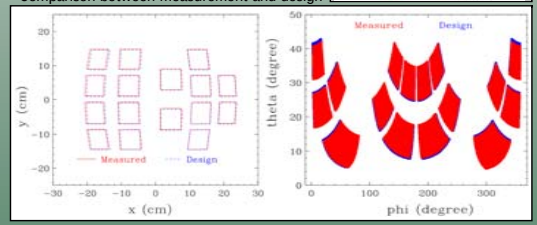
- Separate the residue from the beam
- Measure residue properties (e.g. momentum)
- Beam tracking (to determine beam angle and position at the time of collision) requires knowing where the S800 magnetic elements , with respect to the target
- The magnetic elements are measured in global coordinates

High Resolution Array (HiRA)

- Detect the light particles (deuteron, proton, ^{3}He etc.) produced in the reaction.
- 16 telescopes, all ~35 cm away facing the target
  - Each telescope contains 2 Silicon detectors plus 4 CsI
  - E (middle) detector has 32 strips arranged vertically and horizontally, forming 32×32 = 1024 pixels, each with size ~ 2 mm × 2 mm
  - Inherent angular resolution: ~0.3°
- The scattering angle corresponding to every pixel is known, by determining their positions relative to the target
- The results are compared with the design



Comparison between measurement and design



Target

- $(CH_2)_n$ target of different thickness
- Large target to accommodate large beam spot
- During experiment, the target can be changed using a target ladder
- Center of the target is found using a target mask, which has 5 holes on it
- Need to determine the center of each hole
- Center of the target = position of center hole

Conclusion

- **In the experiment, sub-millimeter (~ 0.3 mm, which corresponds to 0.05°) accuracy is achieved using the Laser Based Alignment System (LBAS), with appropriate analysis method.**
- **The approach used is systematic and general, and can be applied to other experiments.**

Acknowledgement: Lena El-Mogaber, Jenny Lee, Bill Lynch, Andrew Rogers

We acknowledge support from the Summer for Undergraduate Research Experience (SURE) program at the Chinese University of Hong Kong. This work is supported by the National Science Foundation under Grant No. PHY-0606007.

The NSCL is funded in part by the National Science Foundation and Michigan State University.