Development of Time-Of-Flight Neutron Depth Profiling at Penn State University - Preliminary Results

Sacit M. Çetiner
Kenan Ünlü
Penn State University
Radiation Science & Engineering Center
University Park, PA 16802-2304

Gregory R. Downing
NIST

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INTRODUCTION

- Neutron depth profiling (NDP)
- Conventional NDP
  - limitations
- Penn State NDP Setup
- Time-of-Flight NDP (TOF-NDP)
  - need
  - possibilities
- Penn State TOF-NDP Setup
- Preliminary Results

NEUTRON DEPTH PROFILING

- Neutron depth profiling
  - powerful surface characterization technique for certain light elements
  - monoenergetic, isotropic charged particle emission
  - rapid energy loss
  - nondestructive
- Conventional neutron depth profiling (NDP)
  - direct measurement of residual energy
  - SBD, PIPS or Photodiode PIN detectors
- Time-of-Flight NDP
  - particle flight time is measured
  - microchannel plates (MCP) can be used

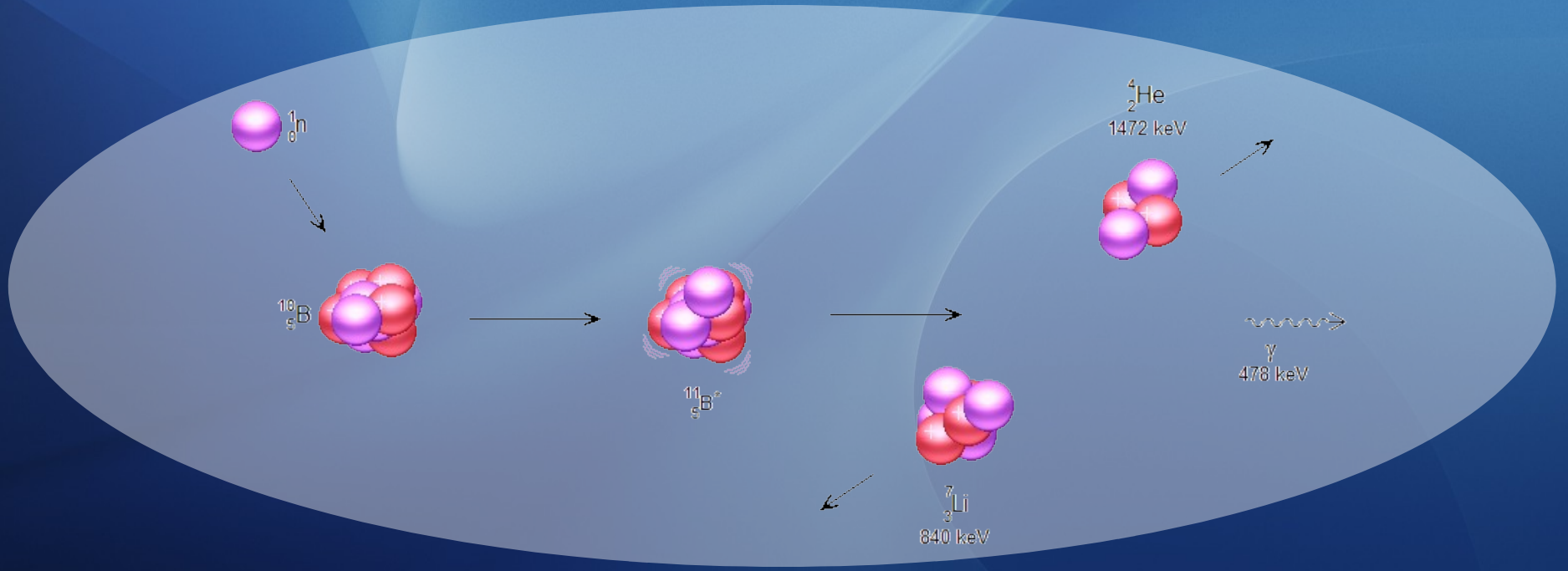
APPLICATIONS OF NDP

- B depth profile in insulation layers such as *borophoshosilicate glass* (BPSG), and implanted B distributions of semiconductor wafers
- He dynamics in technologically important materials
- Li depth profile in lithium niobate ($LiNbO_3$) optical waveguide
- He damage and effusion in fully stabilized zirconia
- Li and N profiles in lithium phosphorus oxynitride (LiPON), and Li profile in lithium cobaltoxide ($LiCoO_2$), two important lithium-ion battery materials

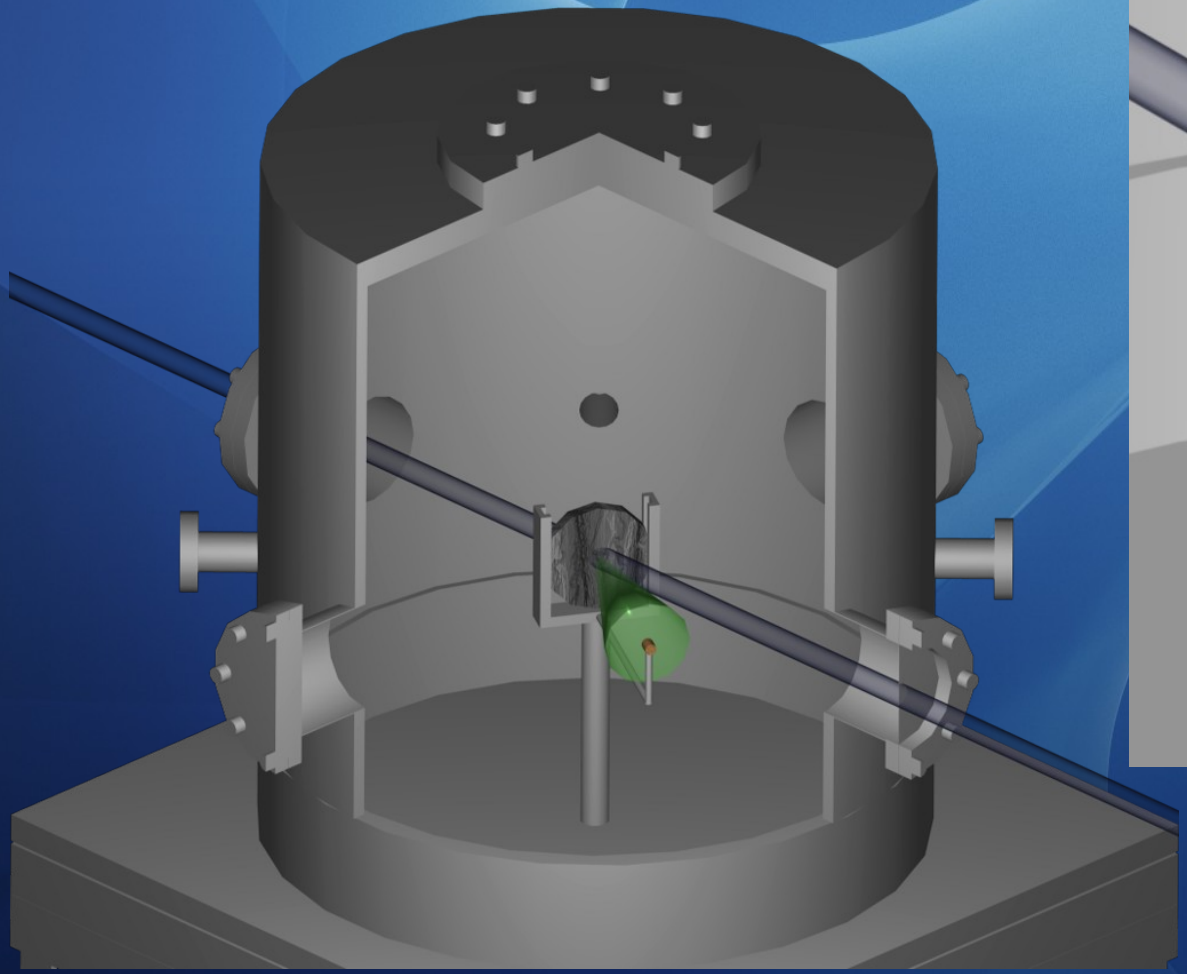
NEUTRON DEPTH PROFILING

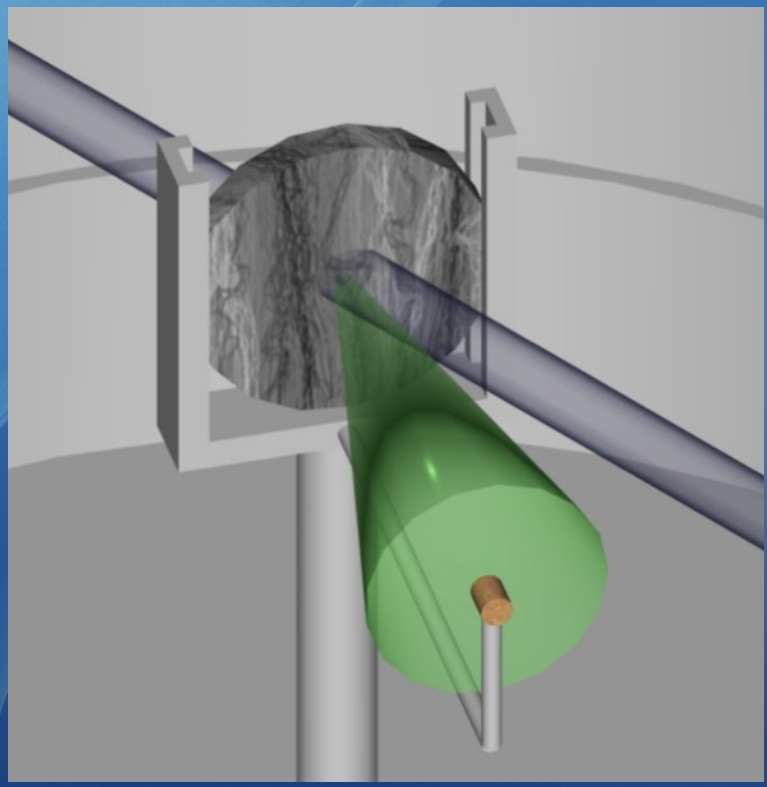
$$^{10}B + n \longrightarrow {}^{7}Li^{*} + {}^{4}He\,(1472\,keV); \quad {}^{7}Li^{*} \longrightarrow {}^{7}Li\,(840\,keV) + \gamma\,(478\,keV)$$

$$^{10}B + n \longrightarrow {}^{7}Li\,(1013\,keV) + {}^{4}He\,(1776\,keV)$$

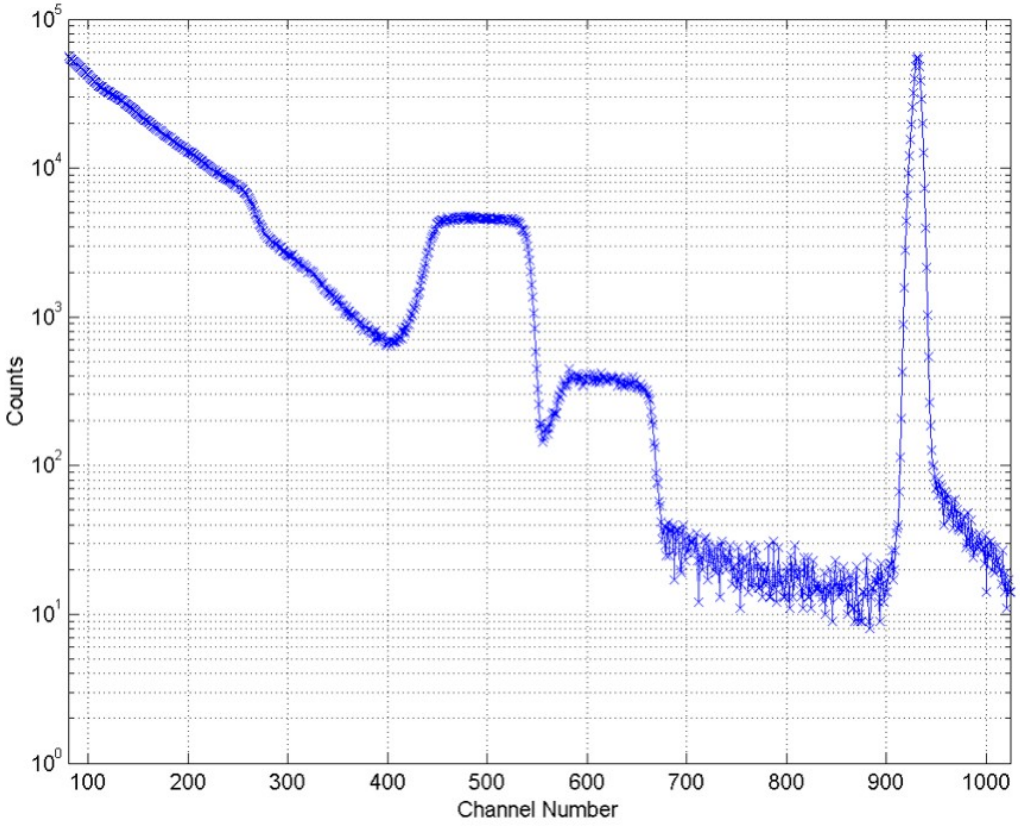


PENN STATE NDP SETUP





BPSG STANDARD SAMPLE



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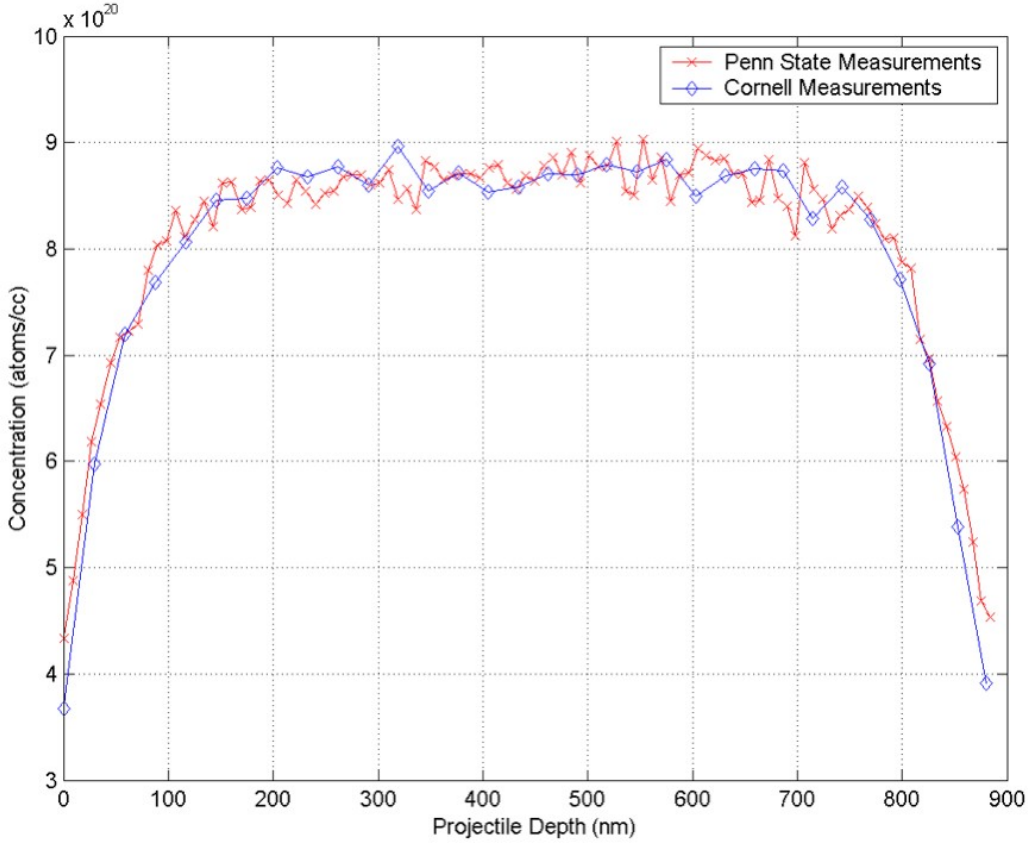
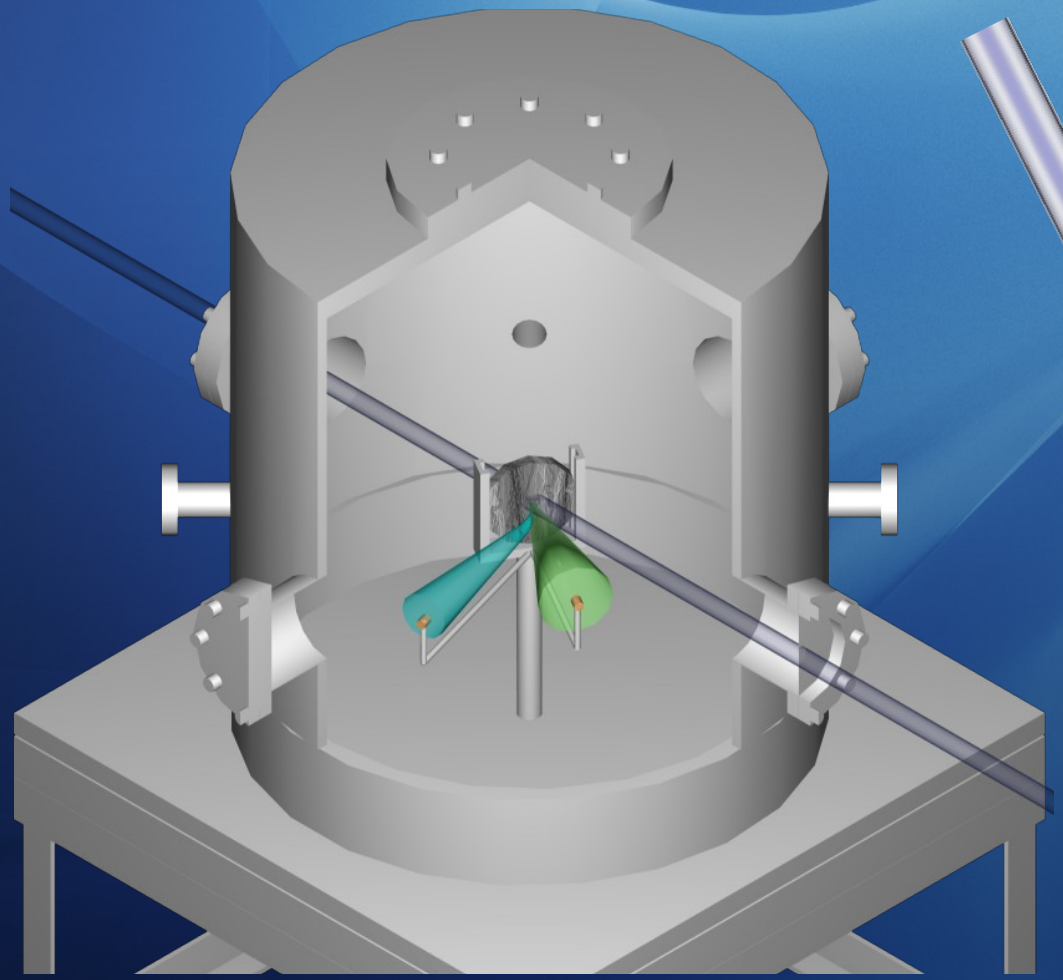
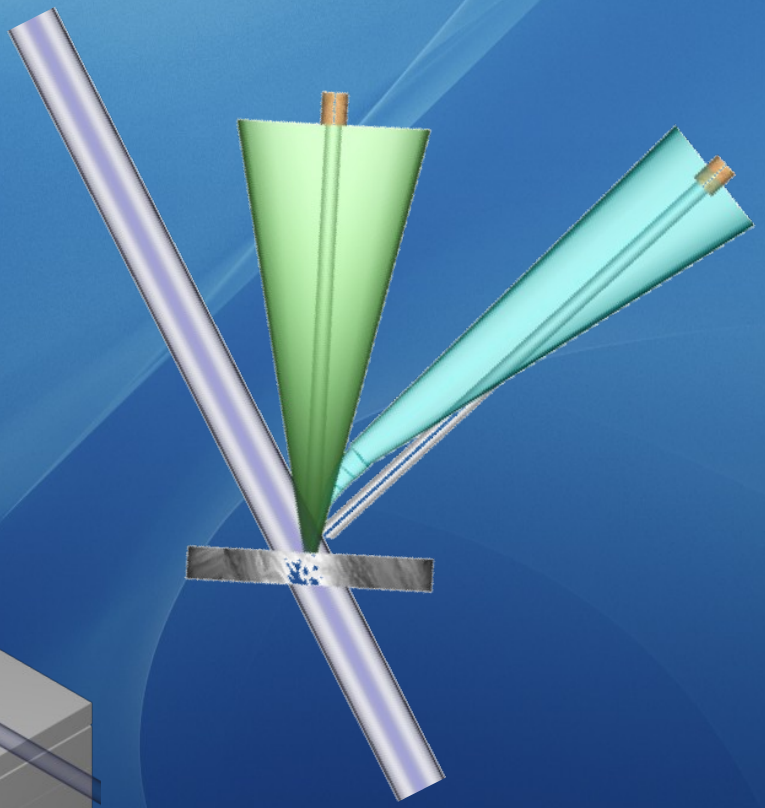


TIME-OF-FLIGHT NDP

- Particle flight time is measured, which is inversely proportional to particle residual energy
- Instead of semiconductor detectors, microchannel plates (MCP) can be used for precise time signals
- Secondary electrons ejected from the surface of the sample as the charged particle emerges are used to trigger the start signal; alpha or recoil give the stop signal

PENN STATE TOF-NDP SETUP

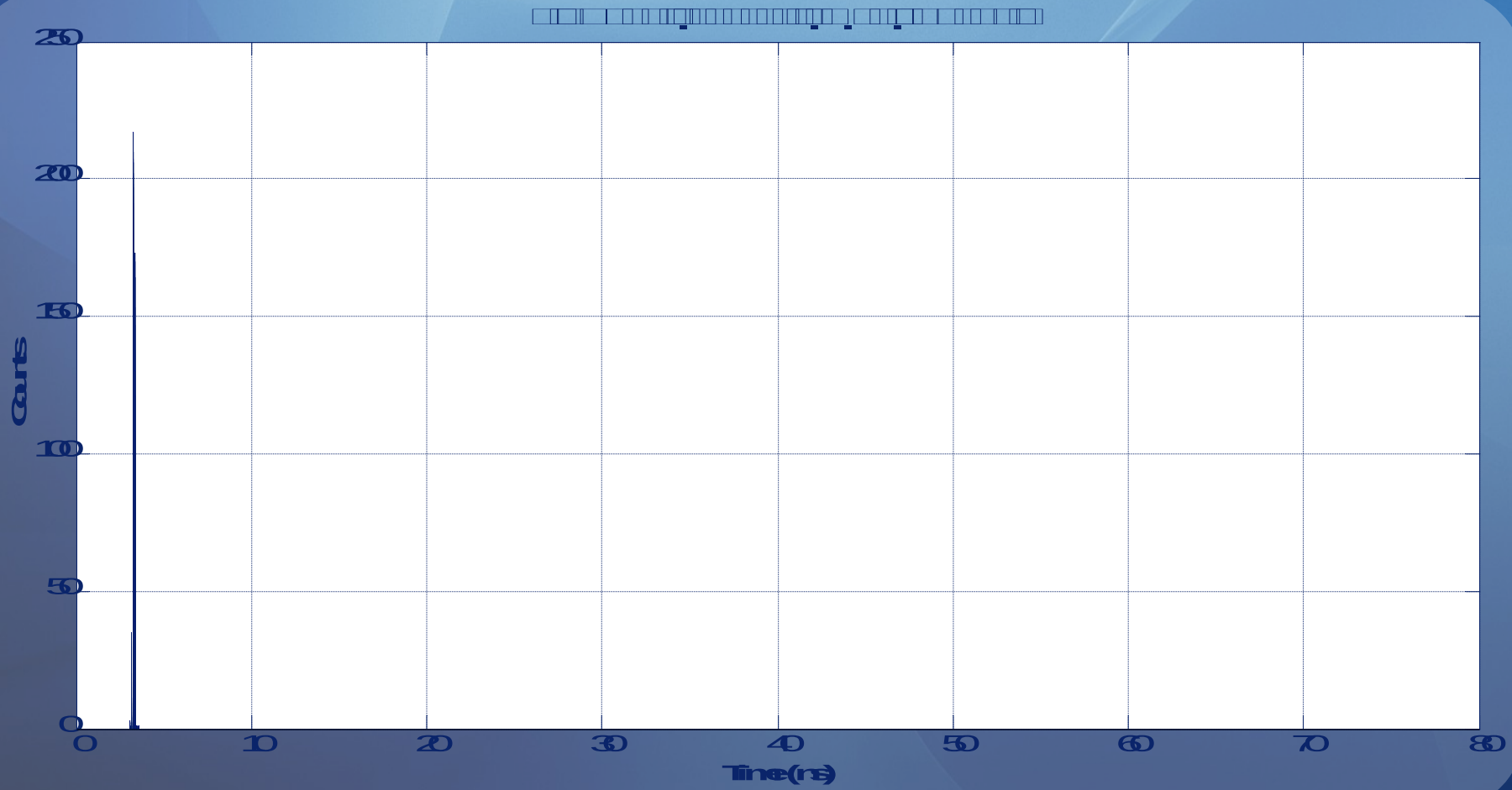




TIME-OF-FLIGHT NDP

- Time-of-NDP is particularly important for depth profile measurements of shallow and ultra shallow source/drain junctions
  - device thickness <200 nm

TIME-OF-FLIGHT NDP: Preliminary Measurements - Offline



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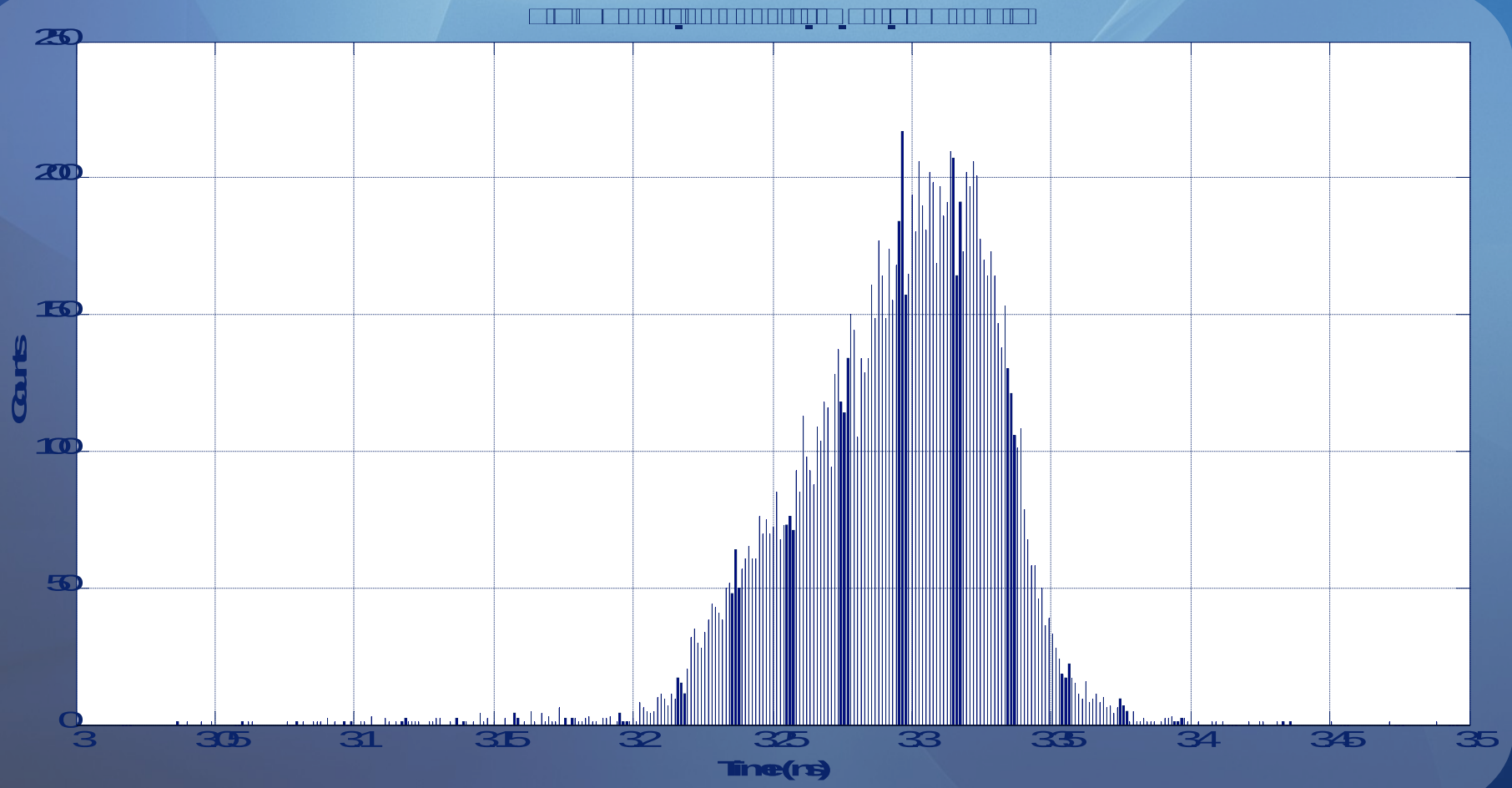
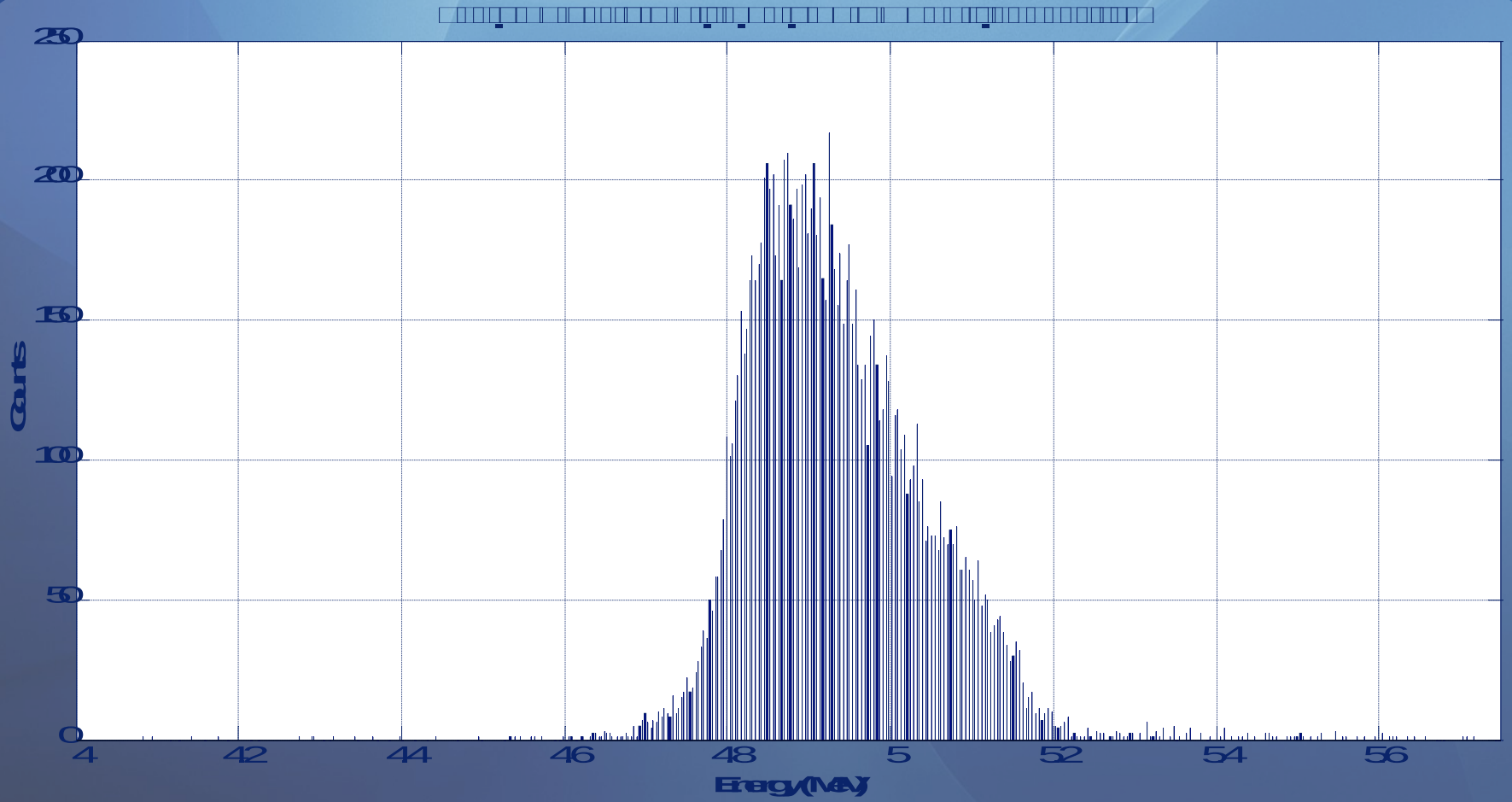
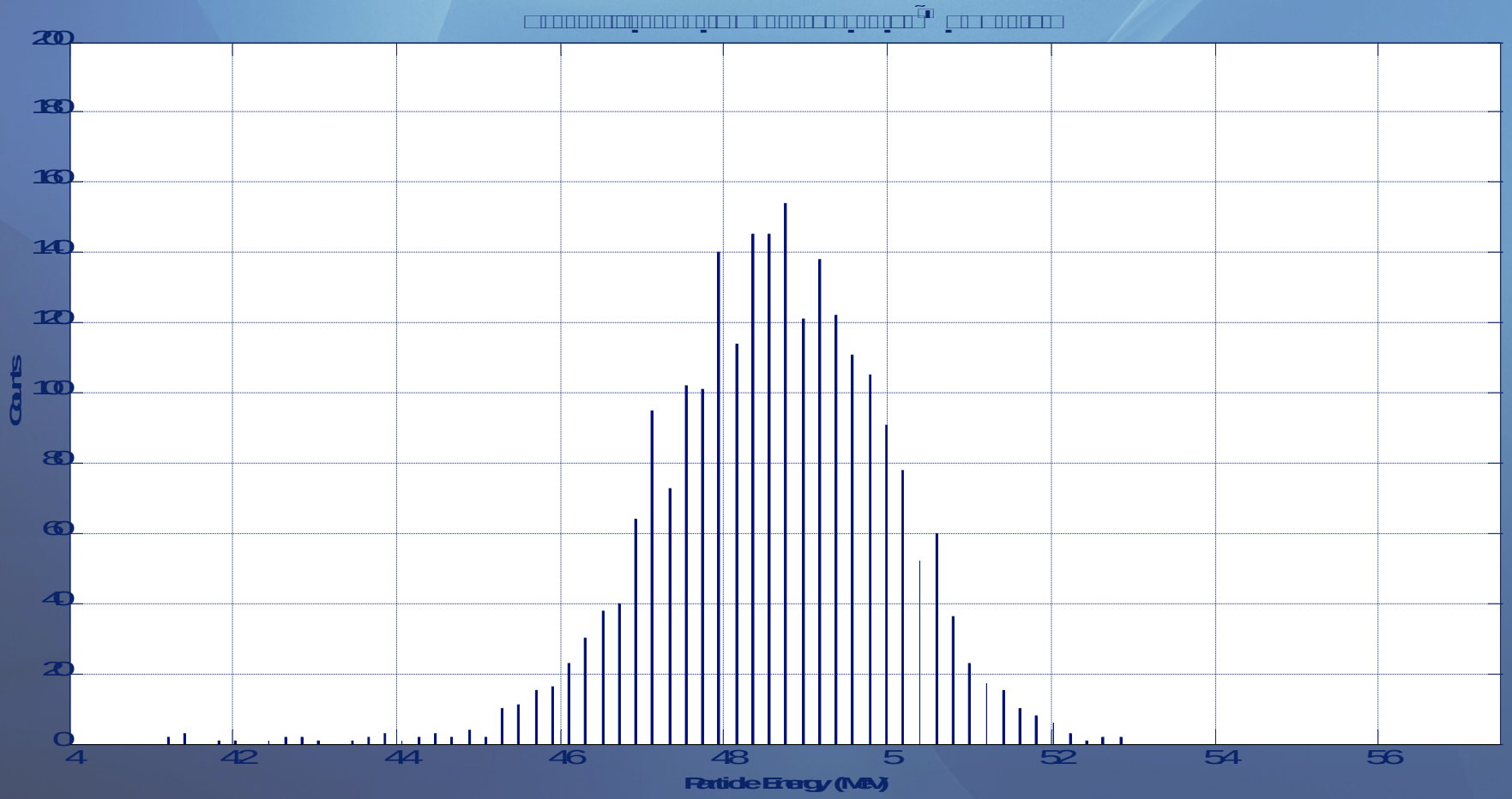


TIME-OF-FLIGHT NDP: Preliminary Measurements - Offline



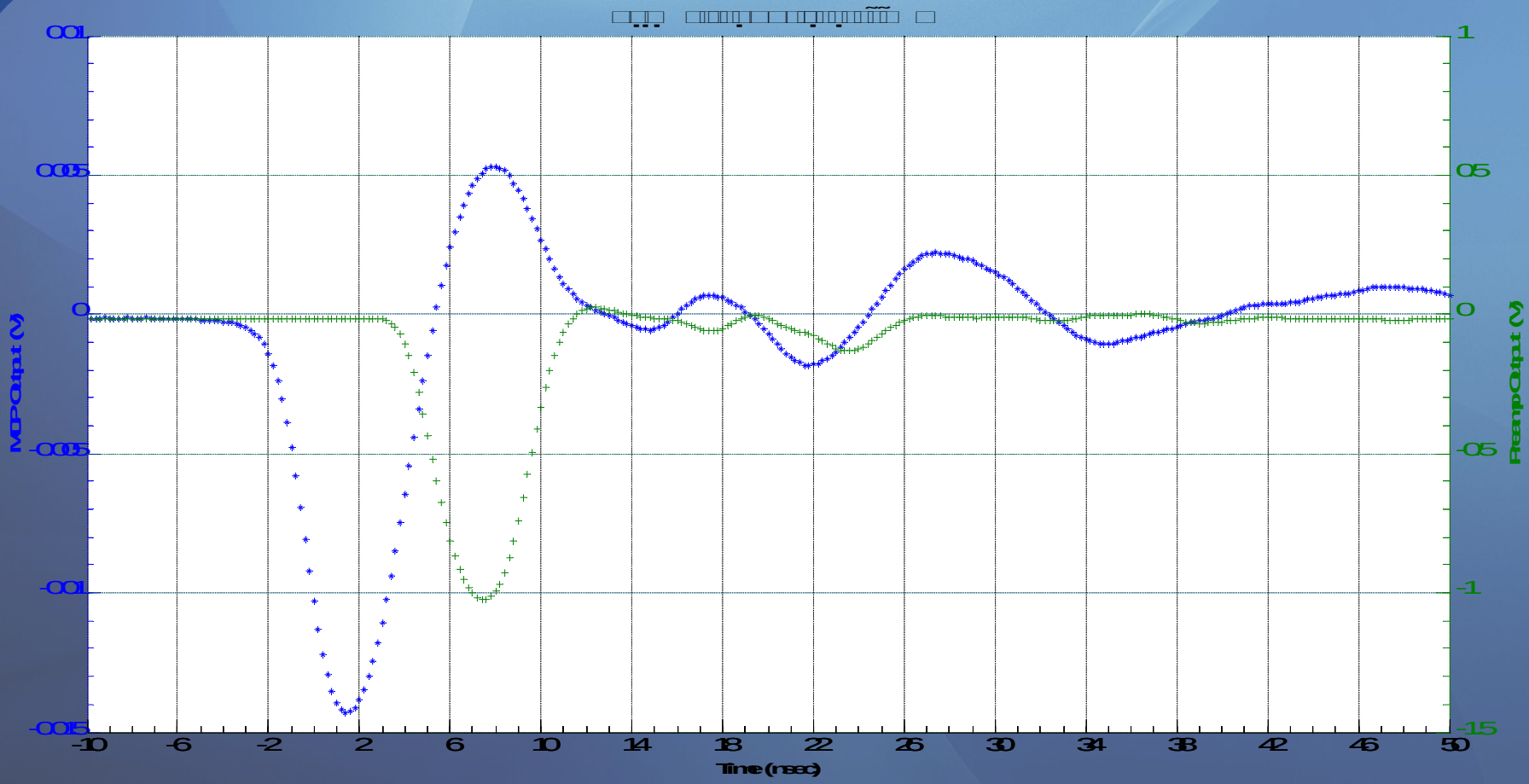
CONVENTIONAL NDP: Same Sample



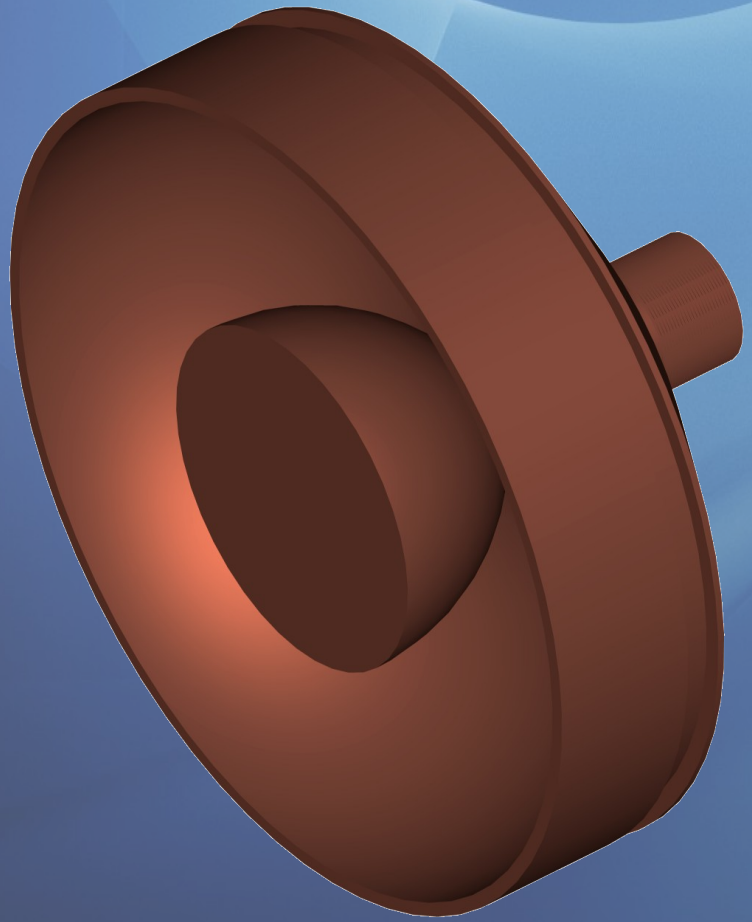
HOW TO IMPROVE

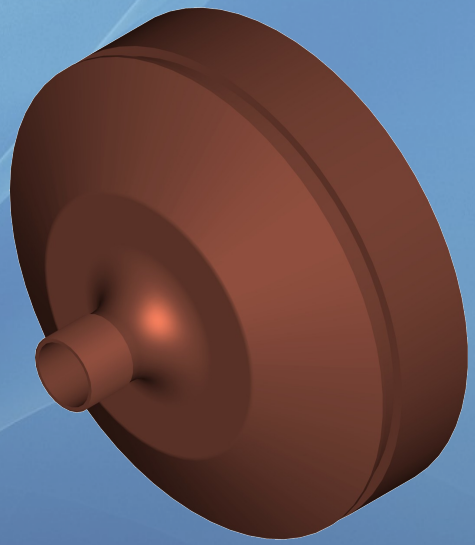
- *Noise elimination*
- Impedance matching along the entire signal transmission line
- Microchannel plate (MCP) assembly: special conical anode

MCP SIGNAL


MCP Output (V)
Preamp Output (V)
Time (nsec)
0.01
0.005
0
-0.005
-0.01
-0.015
1
0.5
0
-0.5
-1
-1.5
-10
-6
-2
2
6
10
14
18
22
26
30
34
38
42
46
50

Signal Improvement: Special Conical Anode

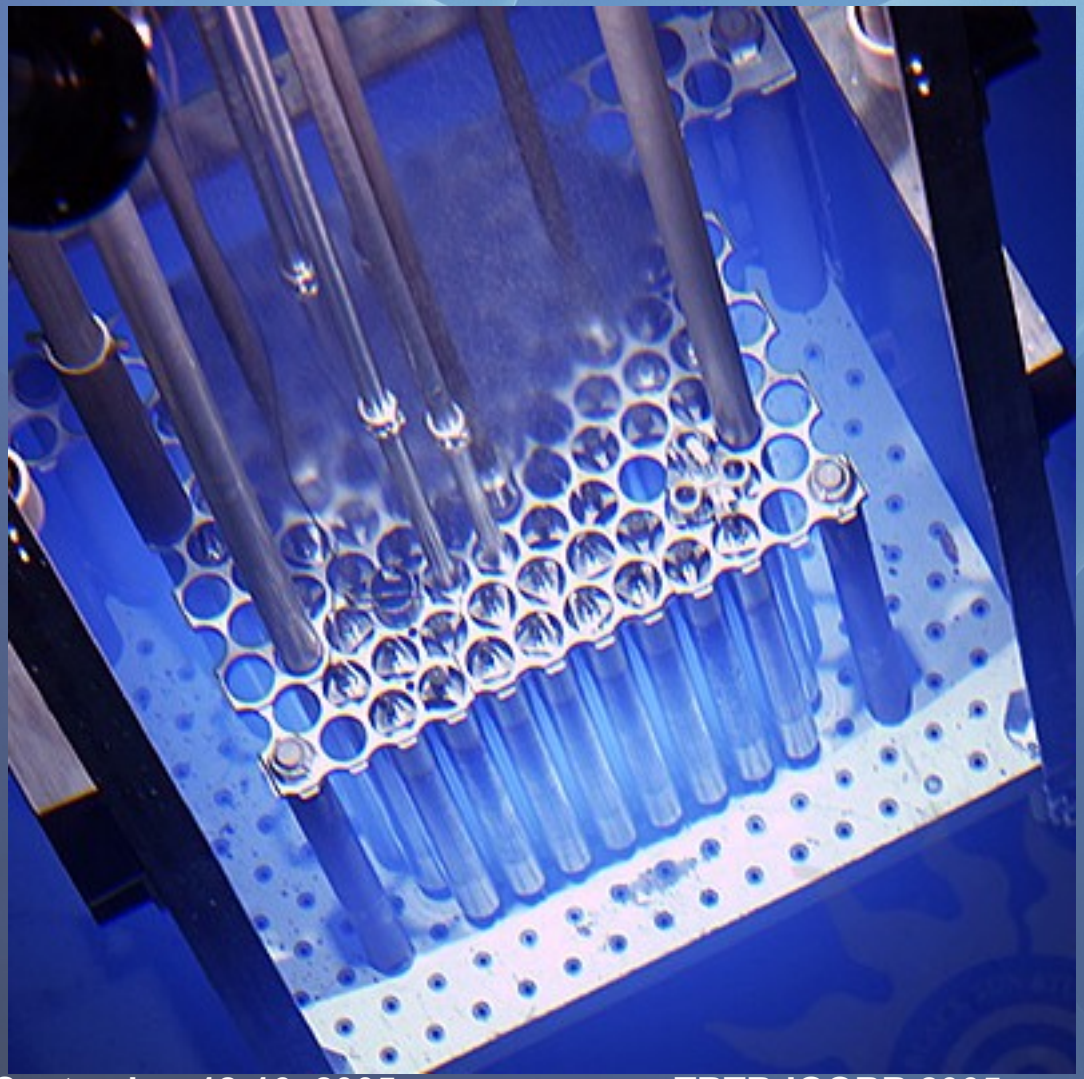




SUMMARY

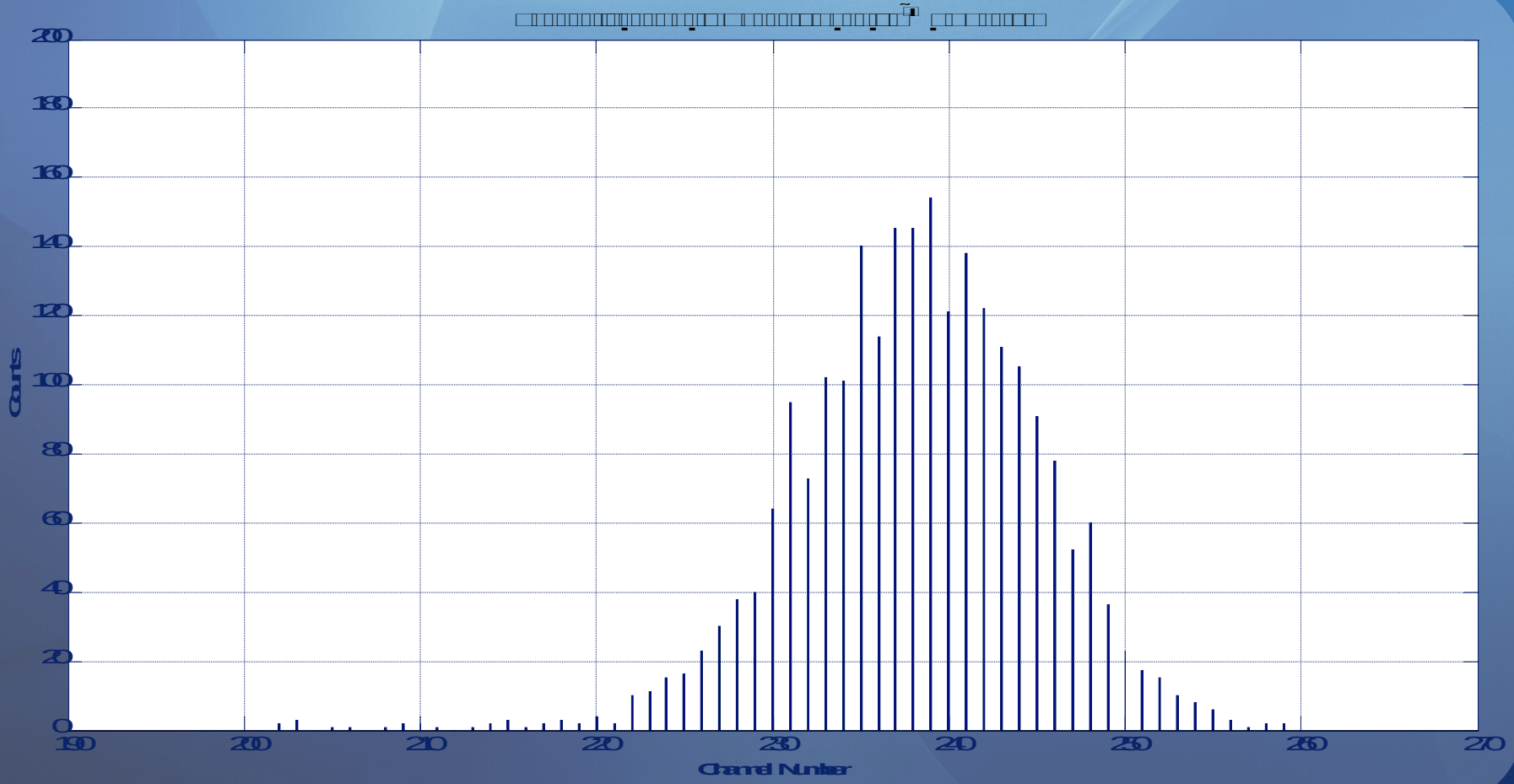
- Preliminary measurement results have been presented
- Further optimization is needed for higher signal resolution
- Improved depth resolution will make it possible to measure B depth profiles in ultra shallow junctions

THANK YOU!

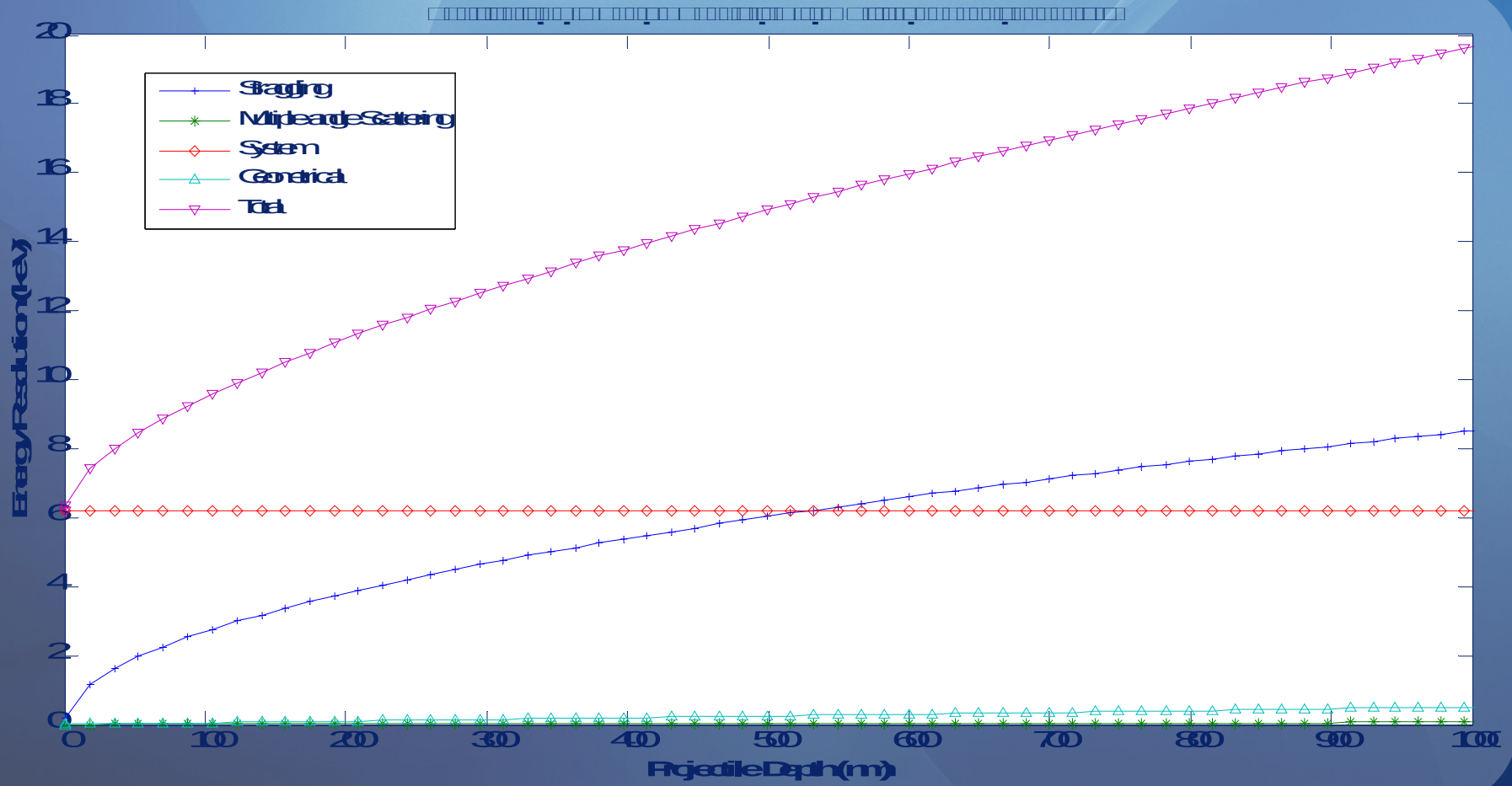


Penn State
Breazeale Nuclear
Reactor during a pulse

CONVENTIONAL NDP: Same Sample



TIME-OF-FLIGHT NDP



TIME-OF-FLIGHT NDP