

Pion Identification from Photonuclear Experiments at MAX lab

by Colleen Allen



LUNDS
UNIVERSITET



UMass

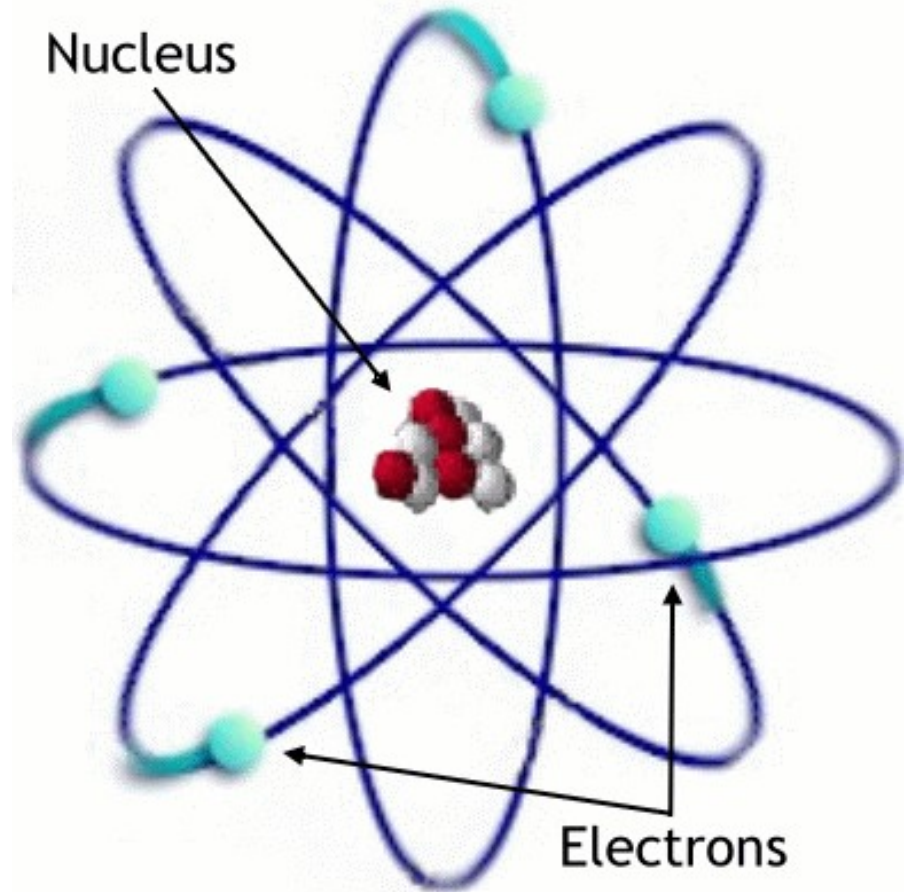
| Dartmouth

International Research Experience for Students (IRES)

- National Science Foundation funded
- Six weeks @ MAX-lab
- Collaboration with The George Washington University, Lund University, Montgomery College and University of Massachusetts Dartmouth
- Undergraduate analysis project

The Atom

- Revolutionary
- A building block of elements
- Our understanding today is a nucleus made up of protons and neutrons
 - But are these the fundamental particles?



Underlying Structure

- Since 1960's-- Quark Model
 - Six flavours
 - Up
 - Down
 - Strange
 - Charm
 - Top
 - Bottom

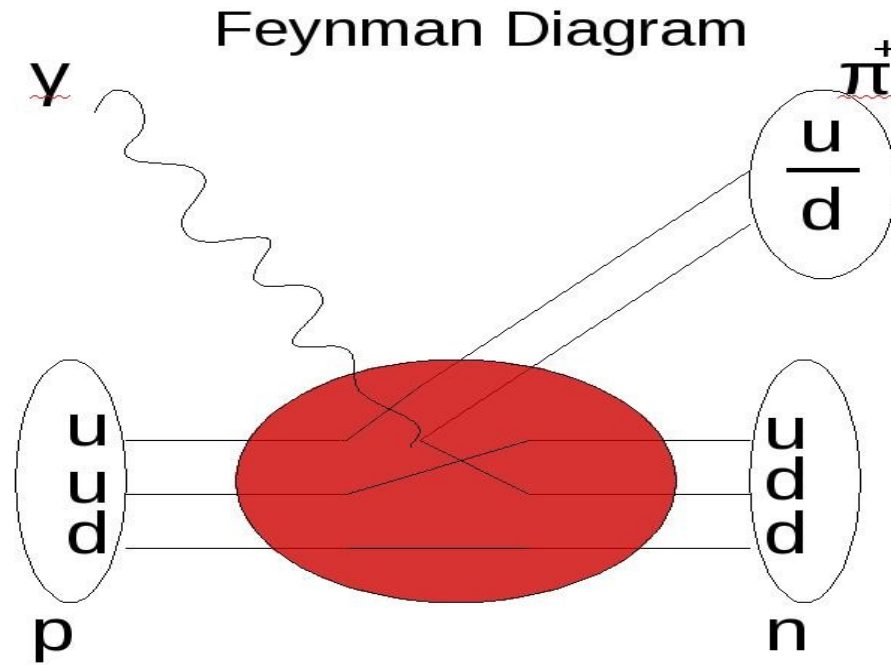
And their antiparticles

How can we study quarks?

- Quarks display confinement
 - Mesons groups of 2
 - Baryons groups of 3
- Quantum Chromodynamics (QCD) theory complicated calculations

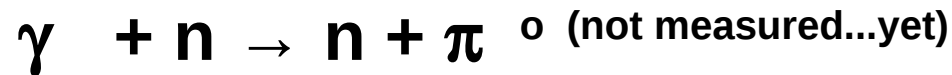
One reaction that is both experimentally measurable and where theoretical calculations can be done is pion photoproduction

- DIRECT rearrangement of quarks

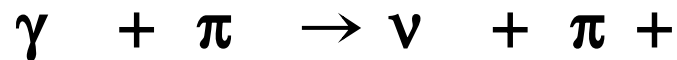
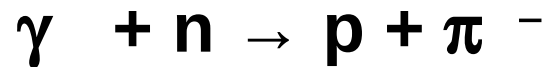


Four channels for pion photoproduction

- Two neutral channels



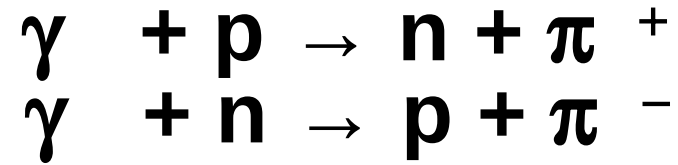
- Two charged channels



Neutral Reactions: $\gamma + p \rightarrow p + \pi^0$

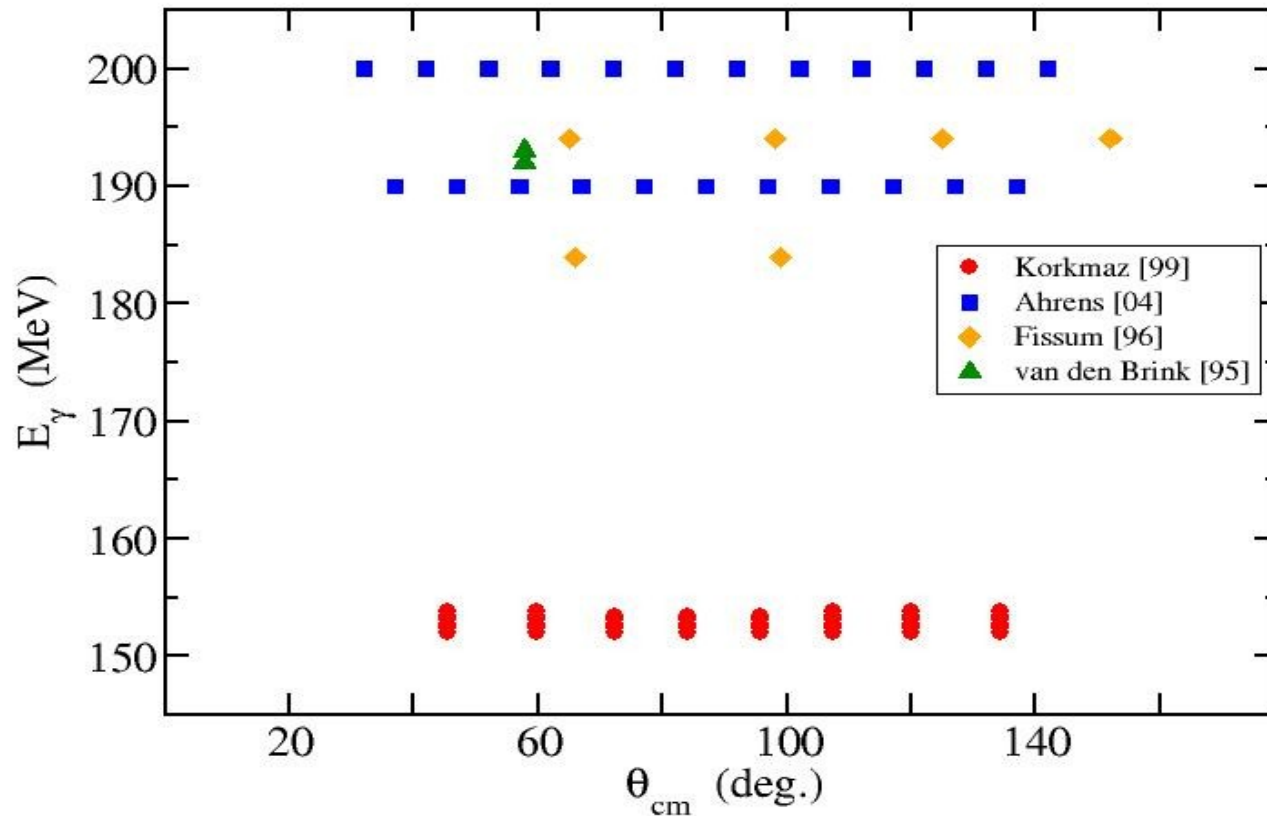
- Many experiments Mainz and SAL
- Over 1200 data points for energies less than 200 MeV
- Cover large energy range and angular distribution
- Good agreement between two locations as well as between theory and experiment

Charged Reactions:



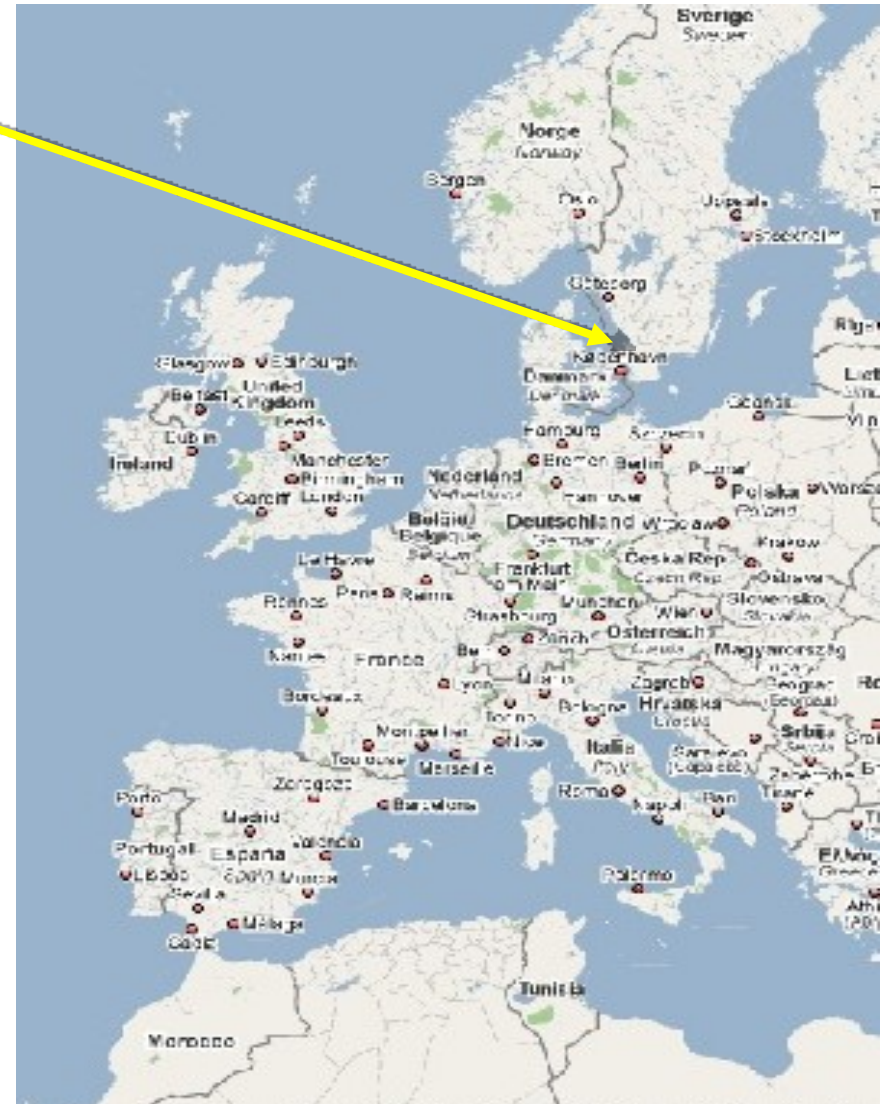
- One recent measurement on each reaction
- Less than 50 data points for each
- Sparse energy range and angular distribution
 - Particularly from 150 MeV-180MeV

Existing Data for $\gamma + p \rightarrow n + \pi^+$

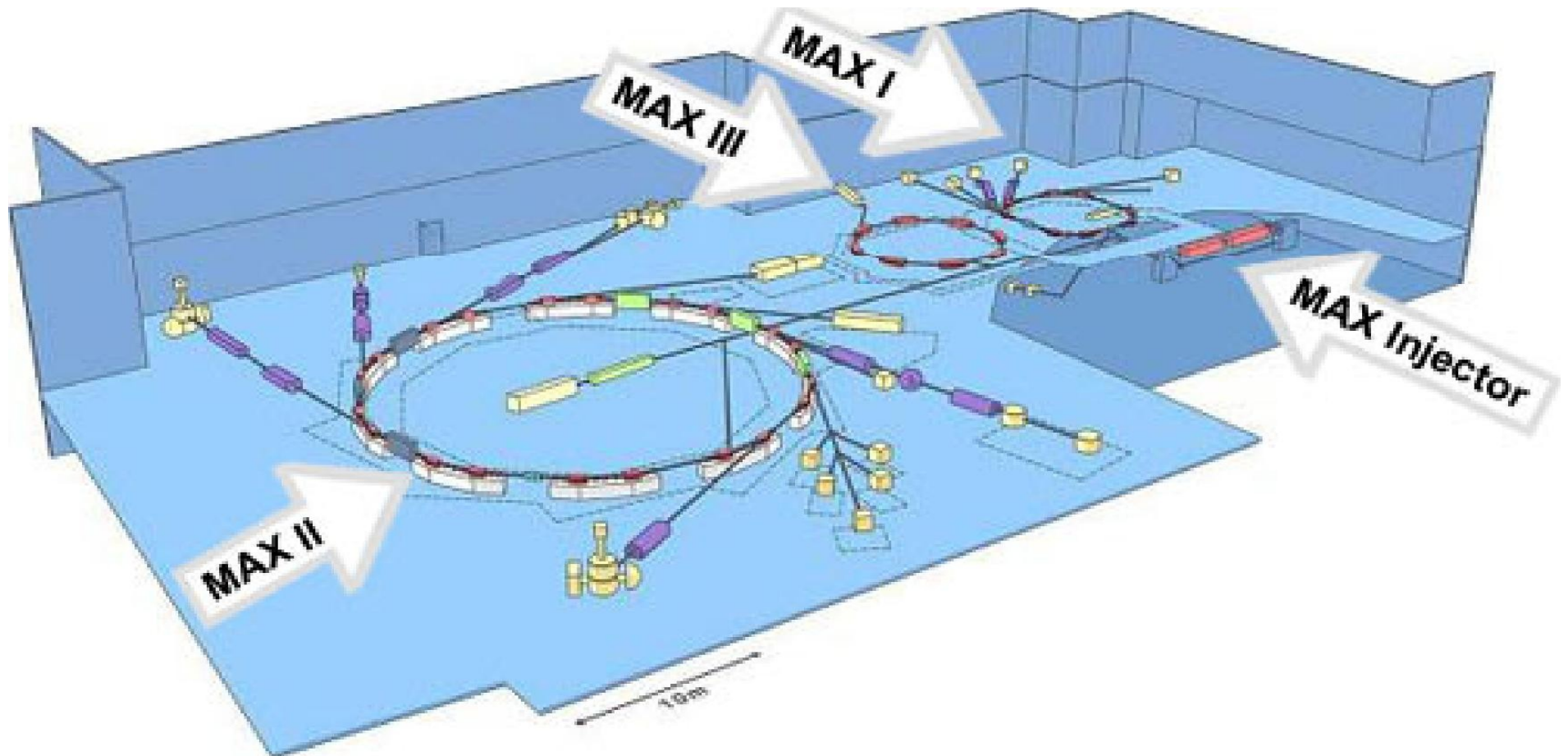


MAX-lab

- Newly upgraded facility at MAX-lab in Lund, Sweden capable of tagging photons up to ~ 200 MeV
- Three major areas
 - Synchrotron Radiation Physics
 - Nuclear Physics
 - Accelerator Physics

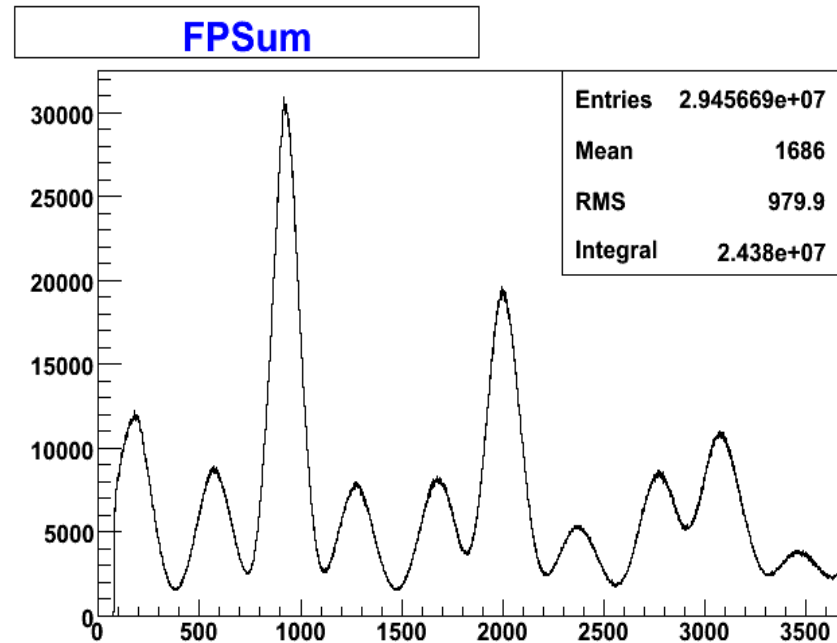
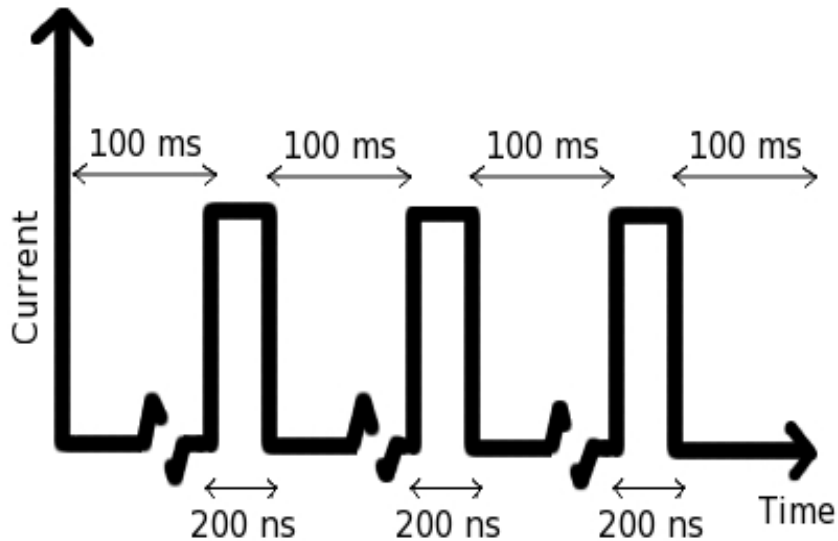


MAX-lab

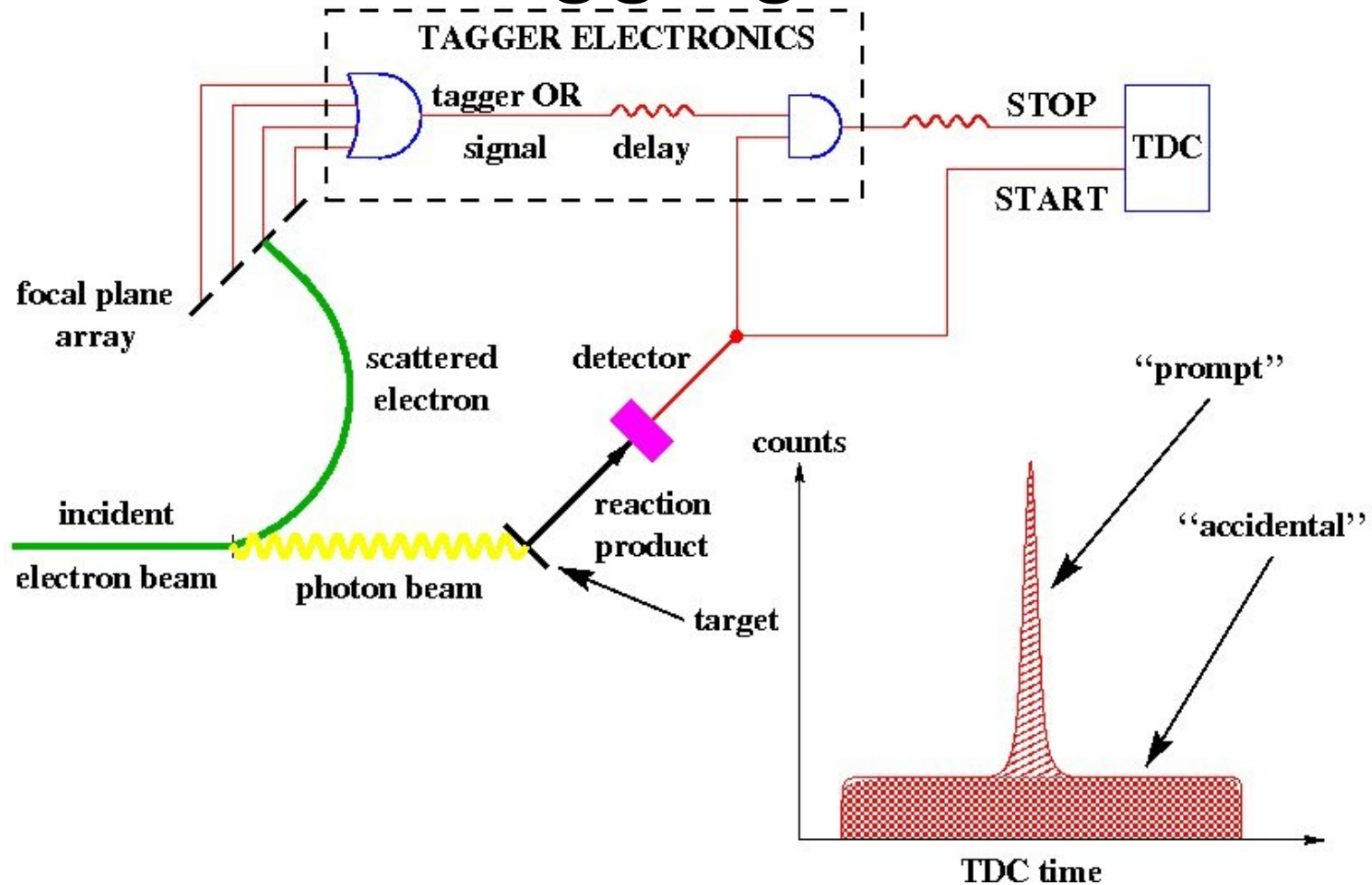


Stretched Electron Beam

- MAX-I pulse stretcher ring provides a nearly continuous beam

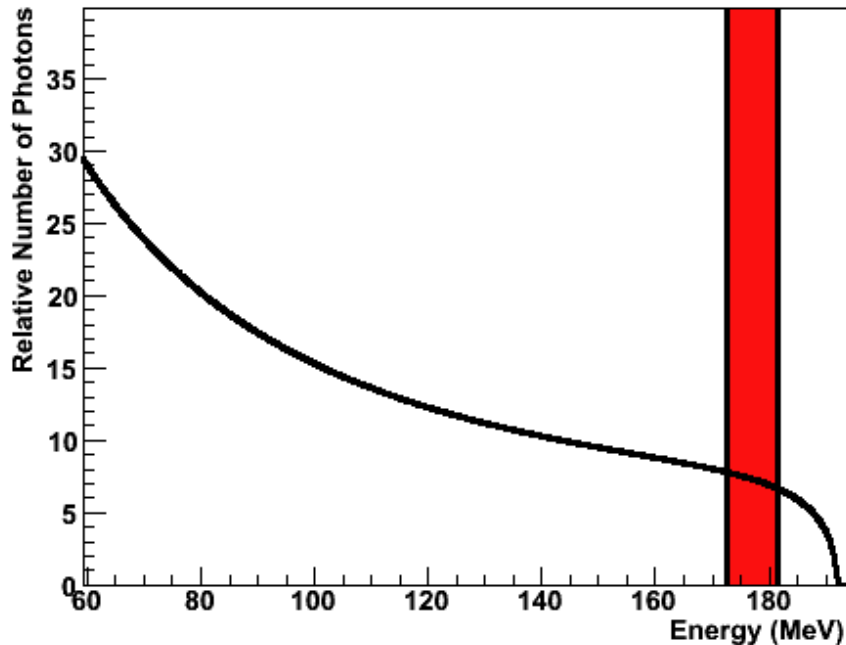


Photon Tagging Schematic



Bremsstrahlung Spectrum

Bremsstrahlung Distribution



- Bremsstrahlung process can produce photons from an energy range of zero to energy of the incident beam

- $E_{\gamma} = E_{\text{beam}} - E_{e^{-}}$

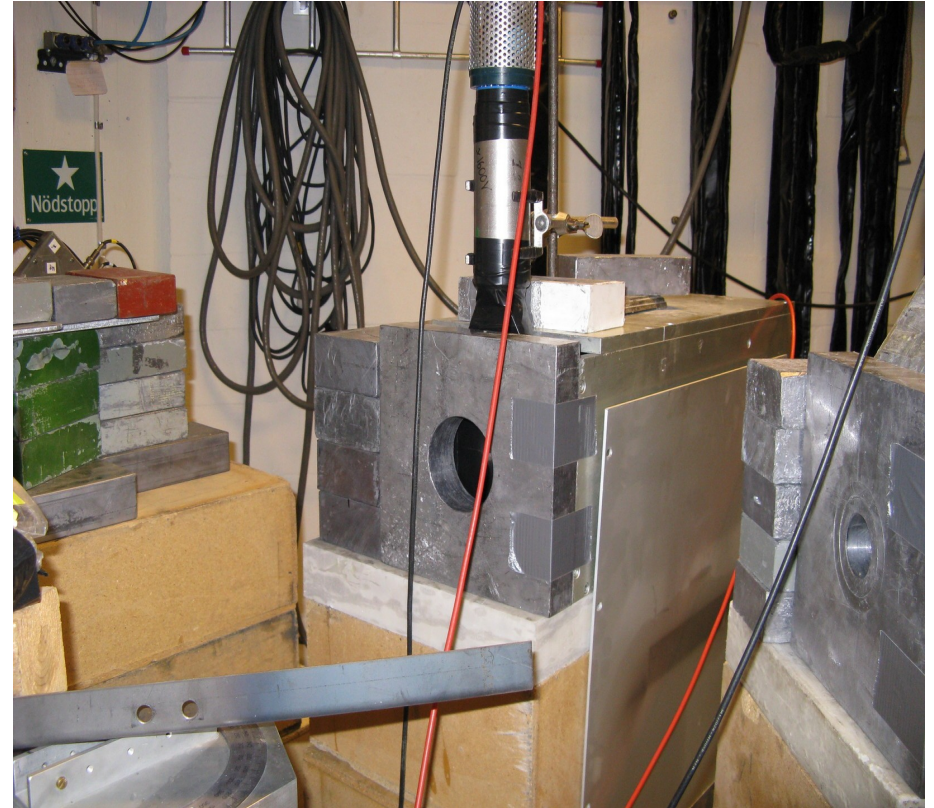
Tagging Efficiency

Important to know how many photons are created and how many make it through to hit the target

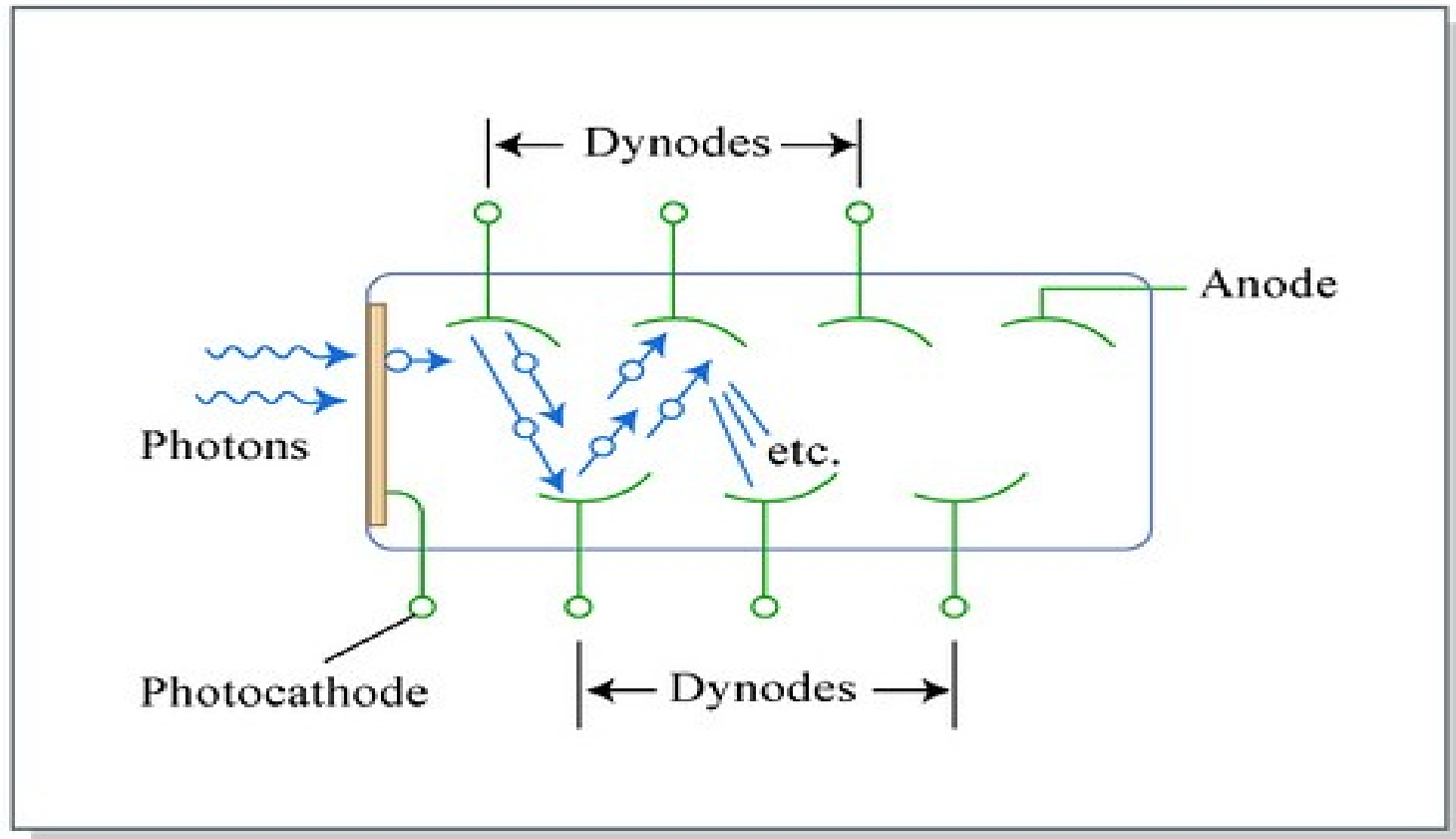
- Each post-bremsstrahlung photon has a corresponding electron that has hit FP array so direct count
- Tagging efficiency runs with Pb-glass
 - ~23% of photons created make it through

Experiment NP014

- Four xSAL detectors
 - 45, 135, 90 both directions
 - Centered around targets of carbon and CH₂
 - Heavily shielded with lead



Scintillation/Photomultiplier Tubes



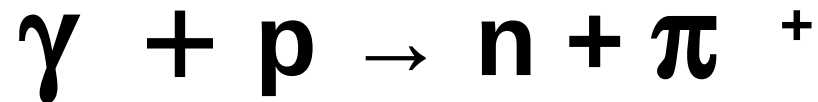
Data Collection

- Production runs began June 3 to June 22, 2009.
- Experimental responsibilities were handled in eight hour shifts, mostly by undergraduate participants
 - Run reports
 - Monitoring beam intensity
 - Detector performance

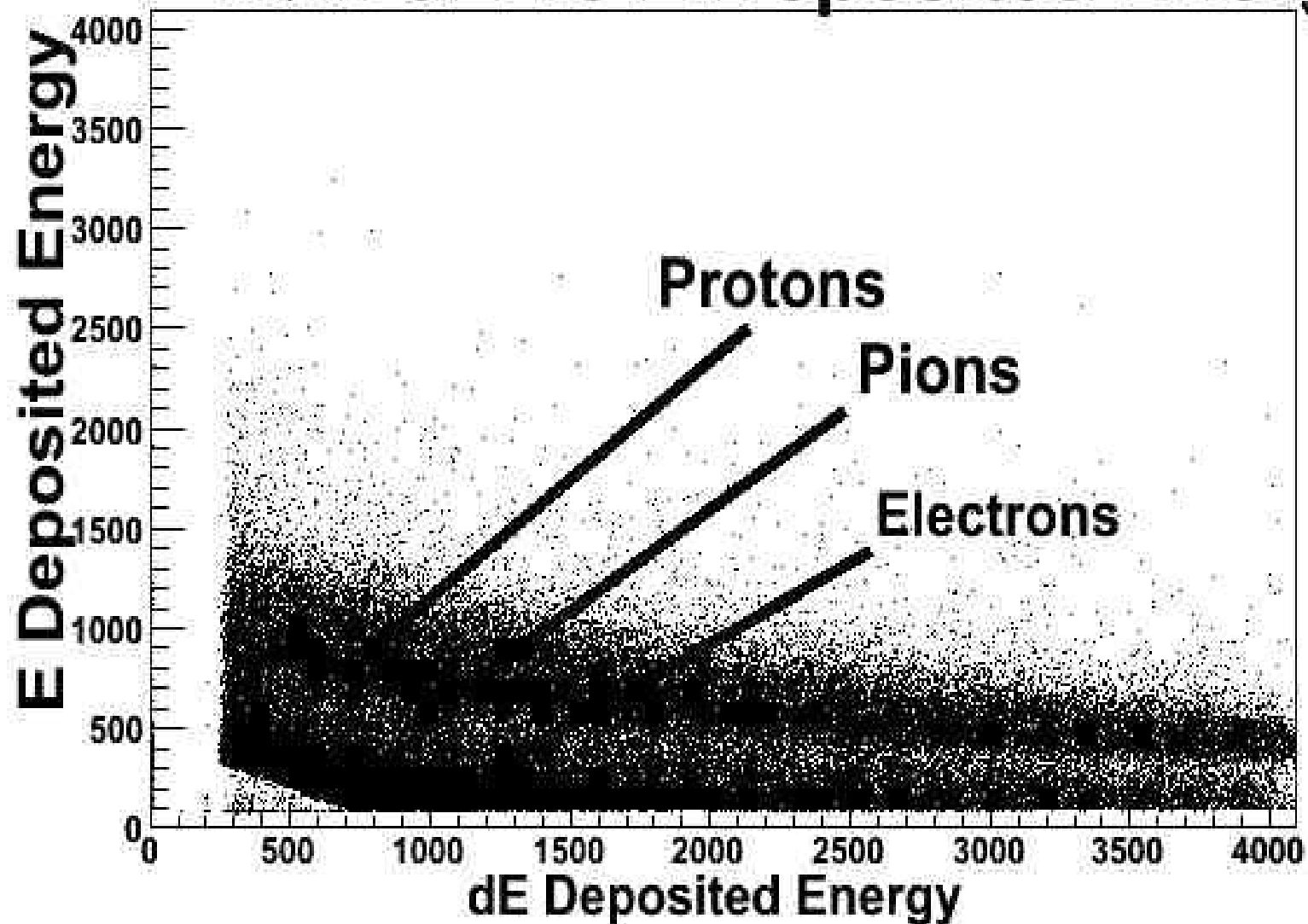
What Happens After the Run Period...

- Data Analysis

Recall we are looking to study pion photoproduction reaction:



Raw dE vs E Deposited Energy

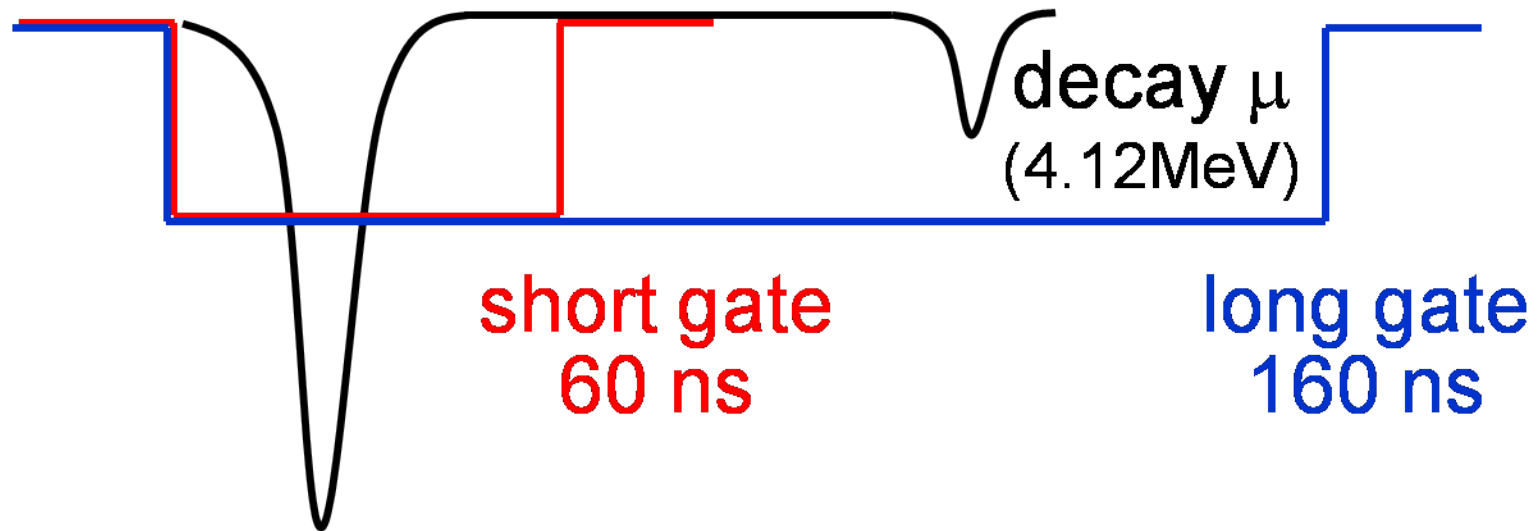


How do we identify pions?

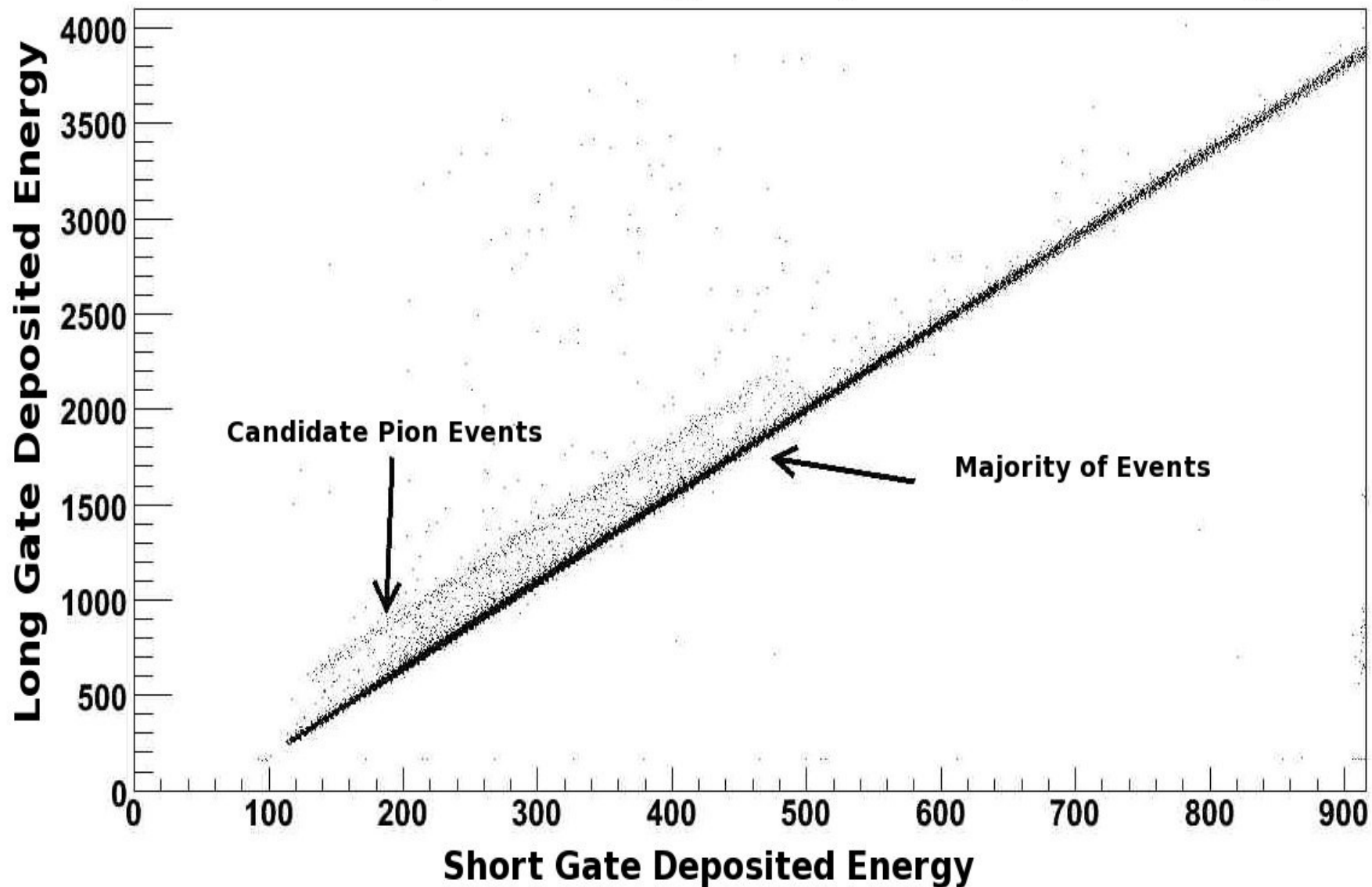
- Standard dE vs E particle identification methods not enough
- We know $\pi \rightarrow \mu$ in 26 ns
 - Lets look for this!

To isolate pion events...

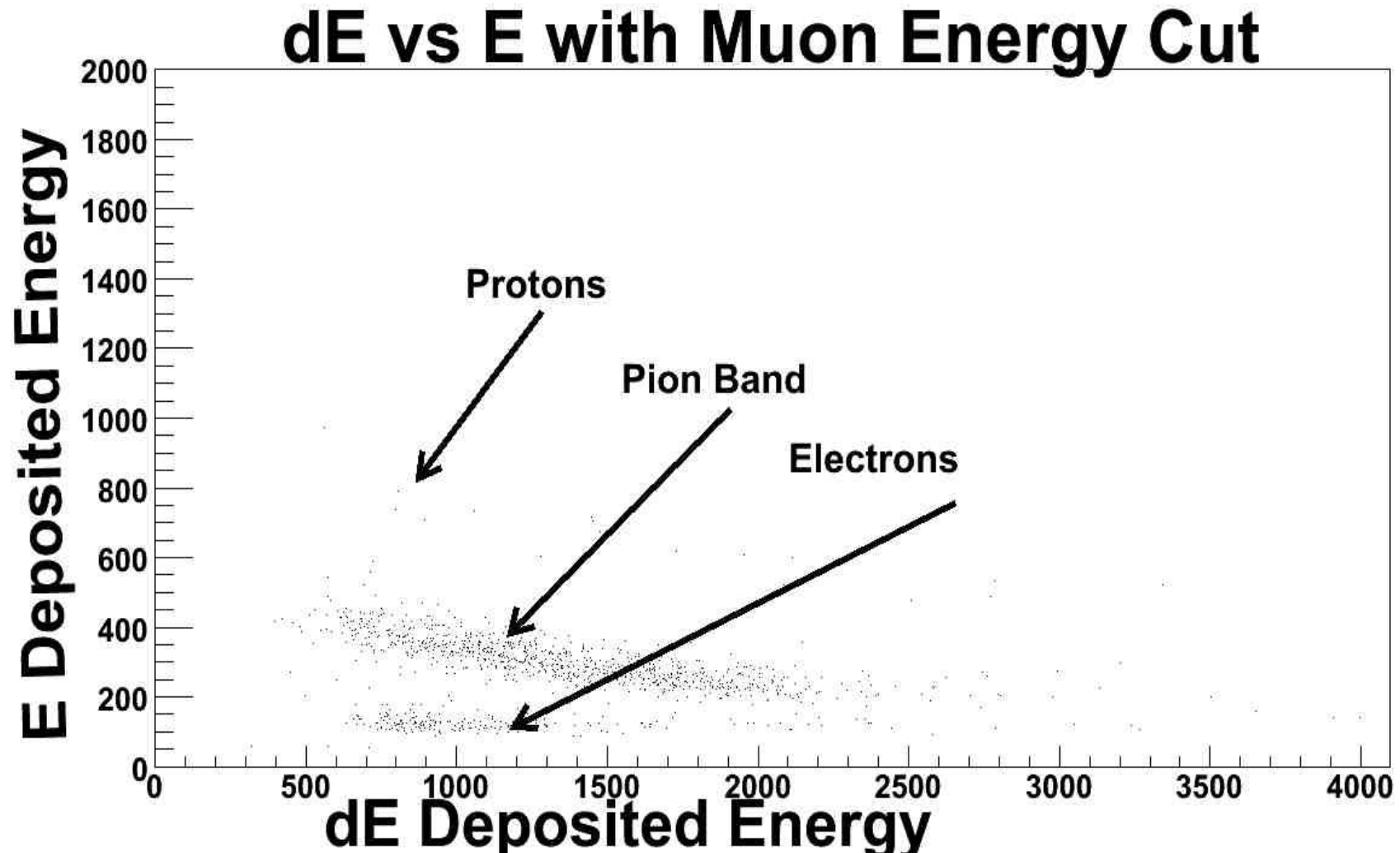
- Send E signal to long gated and short gated QDC (integrates the current of the analog pulse over a user defined time gate)



Short Gate Deposited Energy vs Long Gate Deposited Energy



New dE vs E with selected events

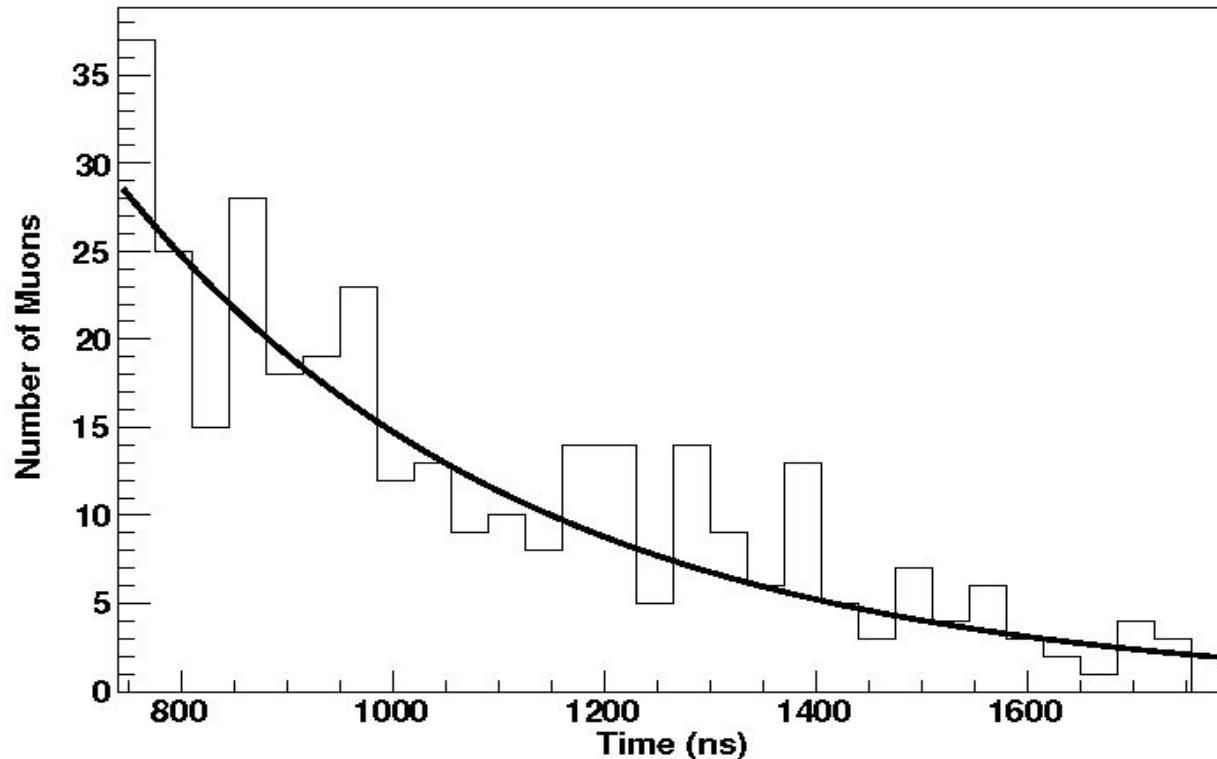


Final Cross Check

Match the known lifetime of 26ns decay

xSAL0 (26.7 ± 1.9) ns

Muon TDC



Conclusion

- Extremely successful run this past summer with 24-hour supervision of experiment
- Successfully identified pions in the detectors
- NEXT STEP: Analyze tagger TDC information to subtract accidental background to get pion yield (needed for cross section calculations)

Thank you!

Thank you to the NSF and MAX-lab for this amazing opportunity.

Thank you to all MAX-lab staff for their patience!

Special thanks to Dr. O'Rielly, Dr. Fissum, Dr. Briscoe and Luke Myers for all your help.

The Future

Duke University

Medical Physics Graduate Program

