The Near-Threshold Pion Photoproduction Program at MAX-lab

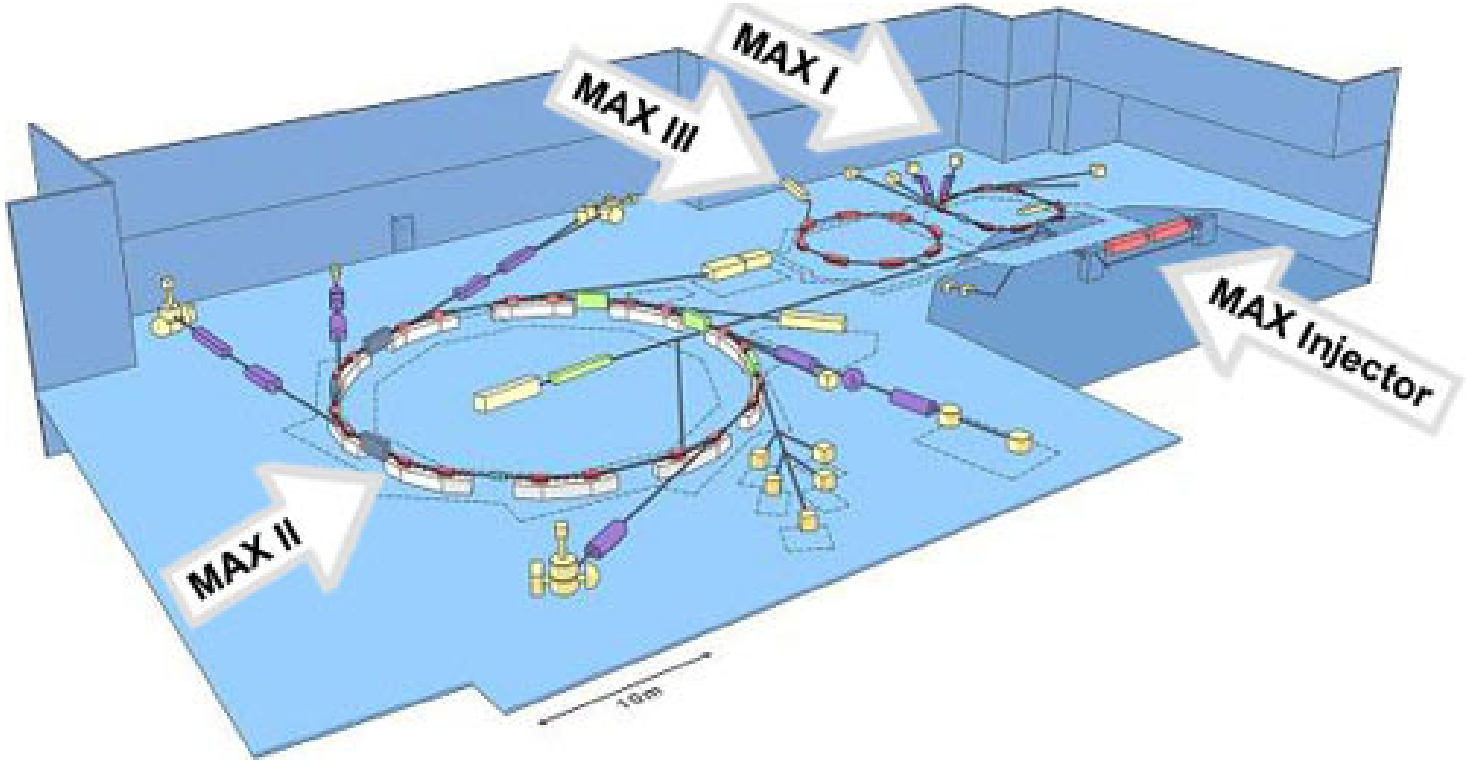
G.V. O'Rielly

University of Massachusetts Dartmouth

for the Pions@MAX-lab collaboration

MAX-lab Facility

- 200 MeV linac + recirculator system
  - inject electron pulse into 3 different storage rings for studies using synchrotron light



Nuclear Physics at MAX-lab

- use the MAX-I ring as pulse-stretcher for nuclear physics experiments available approx. 14 weeks each year

  - photon tagging spectrometer
  - E_γ up to 194 MeV
  - $\Delta E_\gamma \sim 0.4$ MeV
  - rate $\sim 10^6$ γ/MeV/s and $\varepsilon_{tagg} \sim 0.24$

Nuclear Physics at MAX-lab

- MAX-lab ideally suited for studies of photonuclear physics including:
  - (γ,π) below the Δ-resonance
  - compton scattering
  - light nuclei studies
  - knock-out reactions

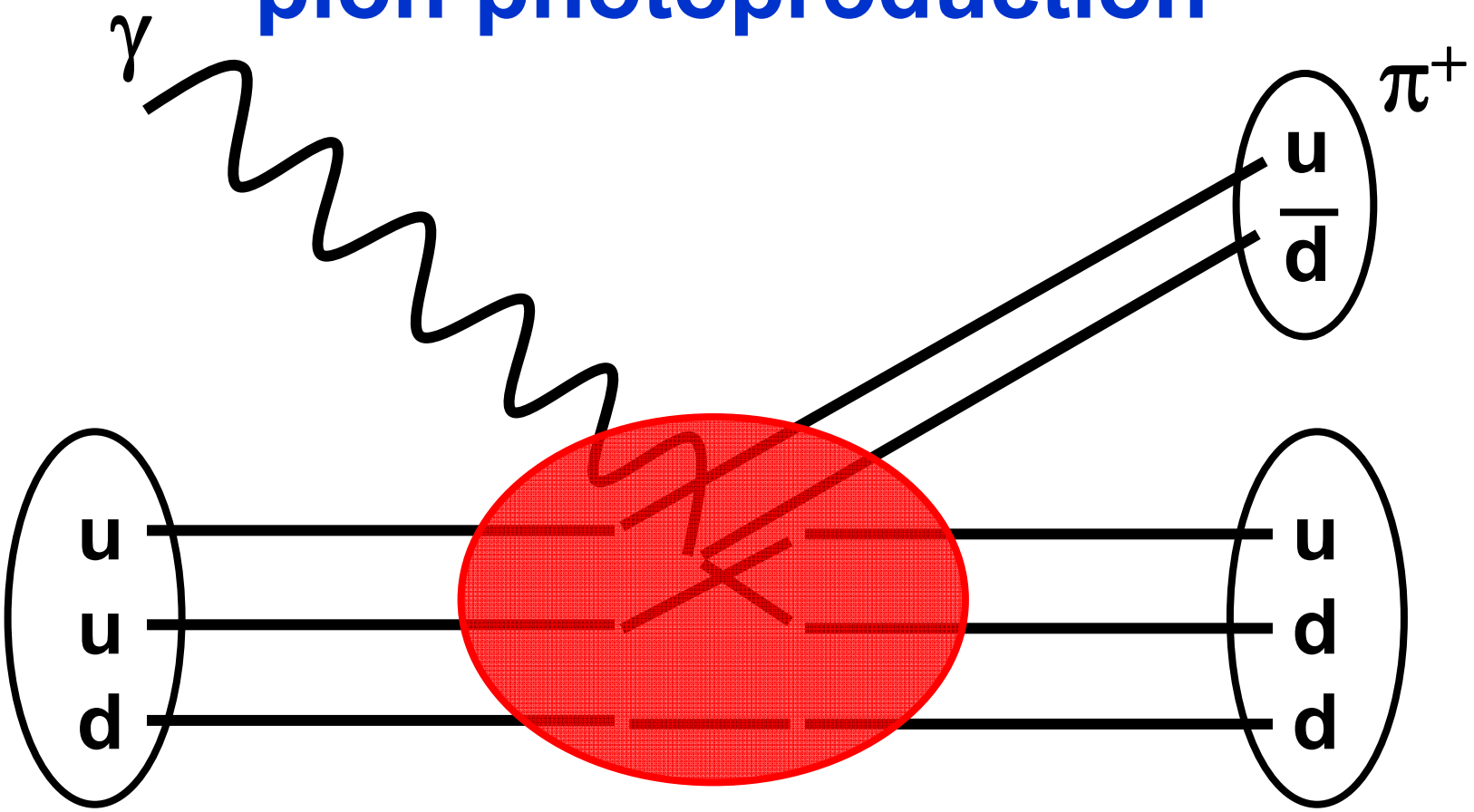
  - excellent training for students

understanding the nucleon

A crucial questions in nuclear science is to connect the observed properties of the nucleon with the theoretical framework provided by QCD

- One approach to answer this is through measurements of pion photoproduction at low-energies
  - involves an explicit rearrangement of the quarks in the nucleon
  - comparison of experimental results with theory provides important test of the various models

pion photoproduction



several Feynman diagrams describing interaction between the γ, p and π

chiral perturbation theory
ChPT

- method to solve QDC in nuclear regime
  - pion & nucleon as appropriate degrees of freedom
  - known symmetries restrict the form of the possible interactions
    - calculations are tractable

- ChPT has been used to predict s- and p-wave contributions to pion photoproduction
  - need to test these against measurements

neutral channel: $\gamma + p \rightarrow p + \pi^o$

- **experiment** (Mainz and SAL)
  - nearly 1200 data points for $E_\gamma < 200$ MeV
    - cover large energy and angular range
    - good agreement between different experiments

- **theory**
  - s- and p-wave multipoles to NLO; $O(p^4)$

good agreement between theory and experiment for the s- and p-waves

charged channels: $\gamma + p \rightarrow n + \pi^+$ $\gamma + n \rightarrow p + \pi^-$

- **experiment**
  - one recent measurement on each channel
    - < 50 data points on each
    - sparse energy and angular coverage
- **theory**
  - ChPT calculations are more difficult
  - only done to leading order; $O(p^3)$

beyond the s-wave ….

- ChPT calculations for $\gamma + p \rightarrow n + \pi^+$ are different than for $\gamma + p \rightarrow p + \pi^o$
  - different structure functions are involved
  - one-loop contributions differ
  - role of counter-terms different

- **it is important to determine the p-wave contributions to $\gamma + p \rightarrow n + \pi^+$**

- **complements work on the neutral channel**

beyond the s-wave ….

- above threshold, p-waves quickly dominate

- explicitly including the p-wave terms, the differential cross section can be expressed as:

$$\frac{d\sigma}{d\Omega} = \left(\frac{q}{k}\right)\left[A(E_\pi) + B(E_\pi)\cos(\theta) + C(E_\pi)\cos^2(\theta)\right]$$

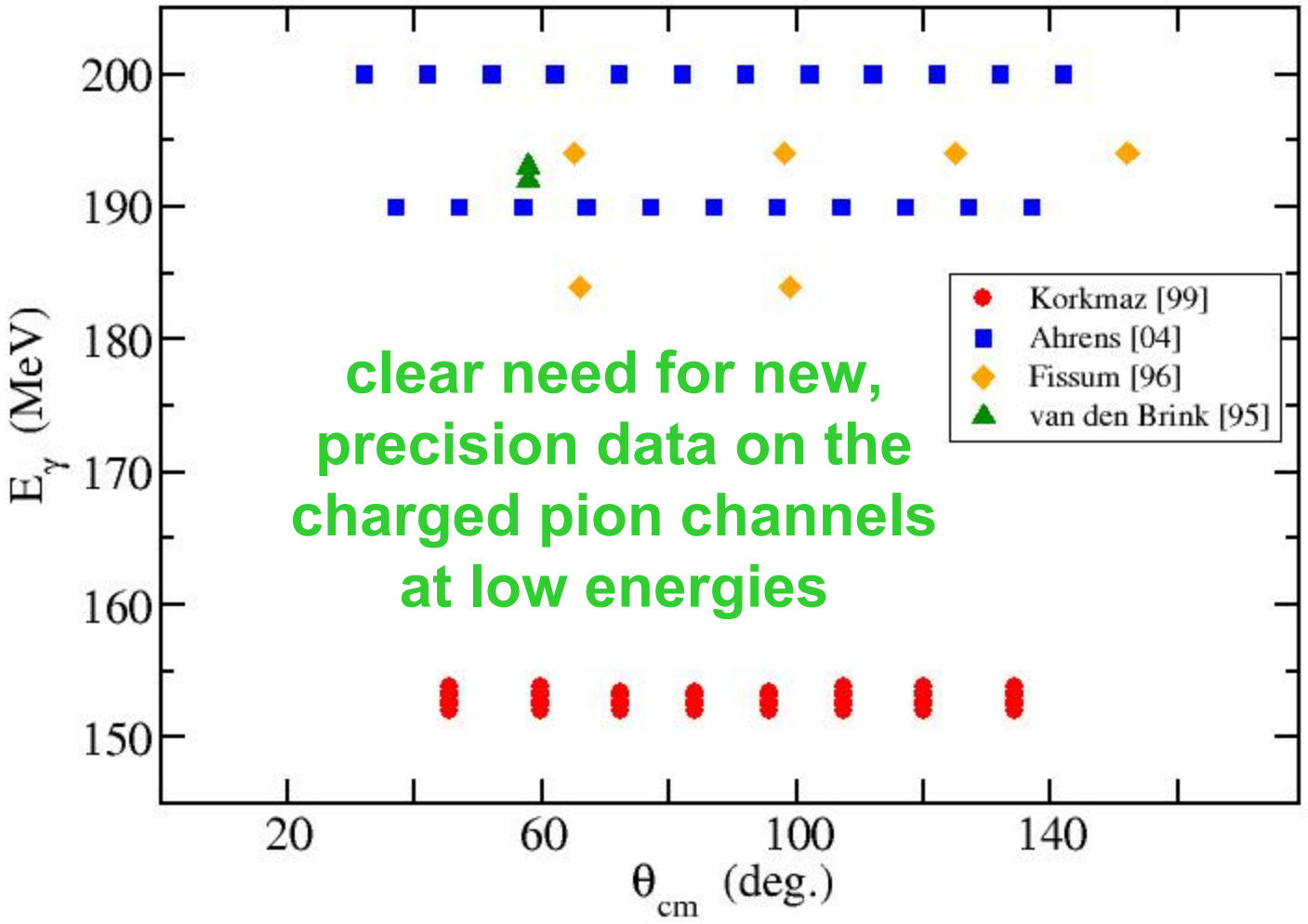
- the parameters A, B and C are related to the E_{0+}, E_{1+}, M_{1+}, and M_{1-} multipoles

beyond the s-wave ….

- fitting the three energy-dependent parameters $A(E_\pi)$, $B(E_\pi)$ and $C(E_\pi)$ to the differential cross sections
  - gives 3 bi-linear combinations of the 4 low-energy multipoles E_{0+}, E_{1+}, M_{1+}, and M_{1-}

- to reliably determine A, B and C
  requires high-quality measurements which cover a large energy and angle range

existing data for $\gamma + p \rightarrow n + \pi^+$



Pion program @ MAX-lab

MAX-lab PAC approved 2 experiments

- NP-014
  - (γ,π^+) differential cross sections up to 200 MeV
  - detect outgoing π^+ in scintillator counters

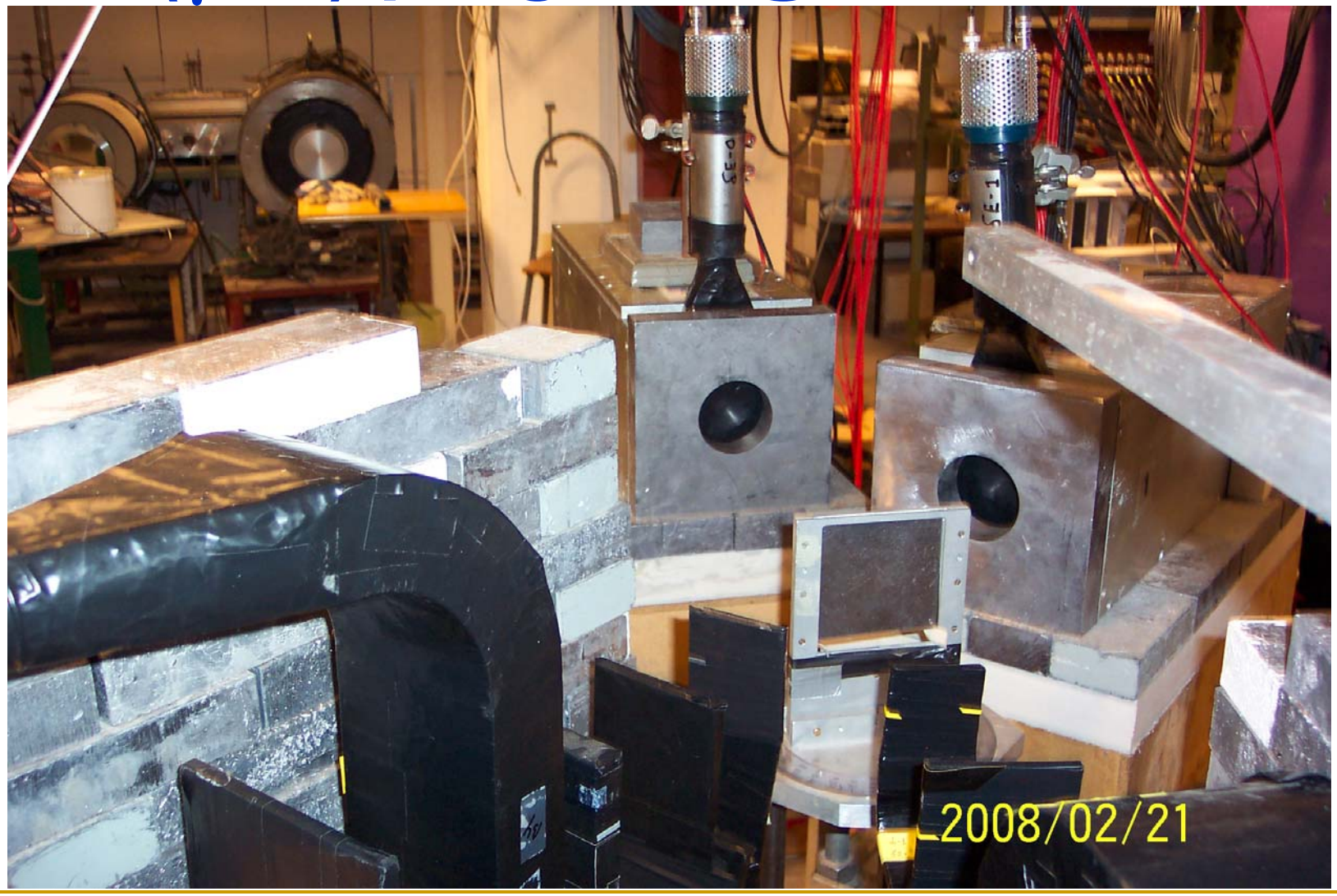
- NP-017
  - (γ,π^-) absolute cross sections near threshold
  - detect 140 MeV γ from π^- capture in LD_2 target

(γ,π^+) program @ MAX-lab

- **MAX-lab program**
  - solid targets (CH_2, C, CD_2)
  - plastic scintillator telescopes at various angles

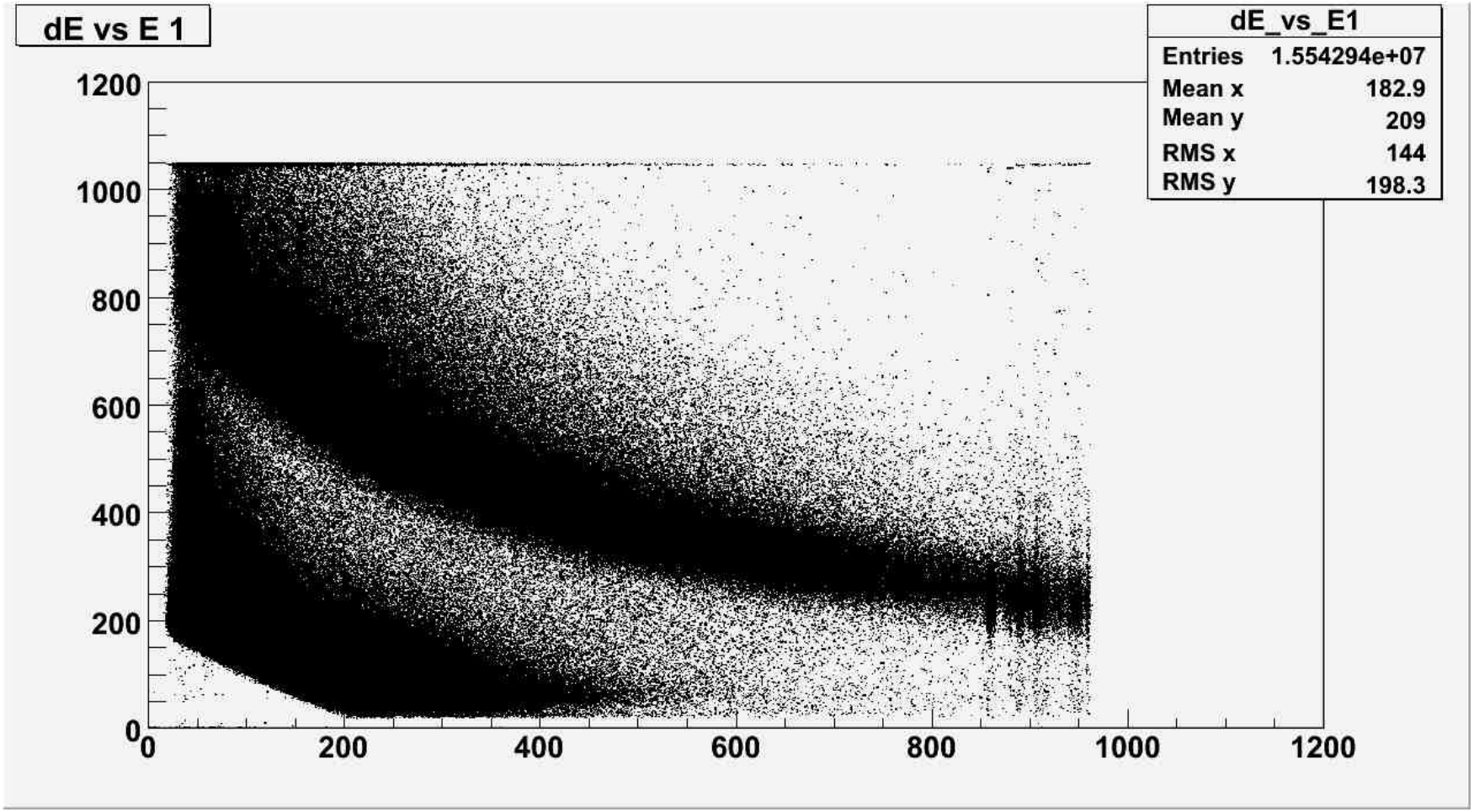
- straight-forward measurements
  - simple target and detectors
  - well understood pion ID and efficiencies
  - standard analysis methods

(γ,π^+) program @ MAX-lab



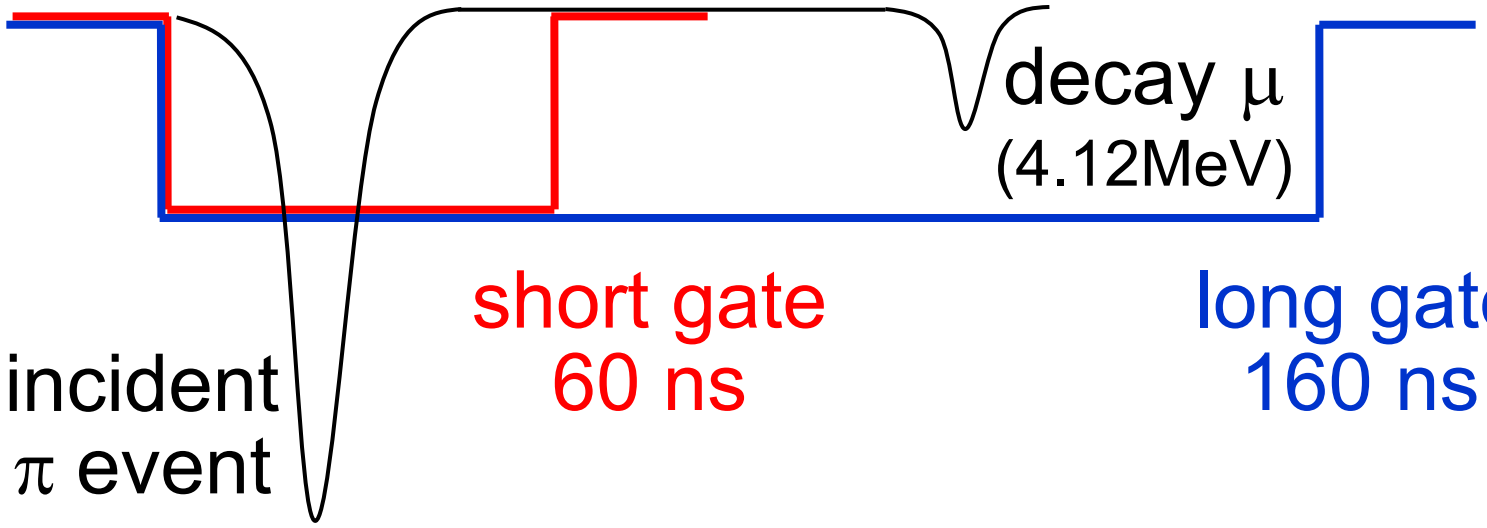
π identification

- ΔE vs E stopping power



π identification

- π → μ decay



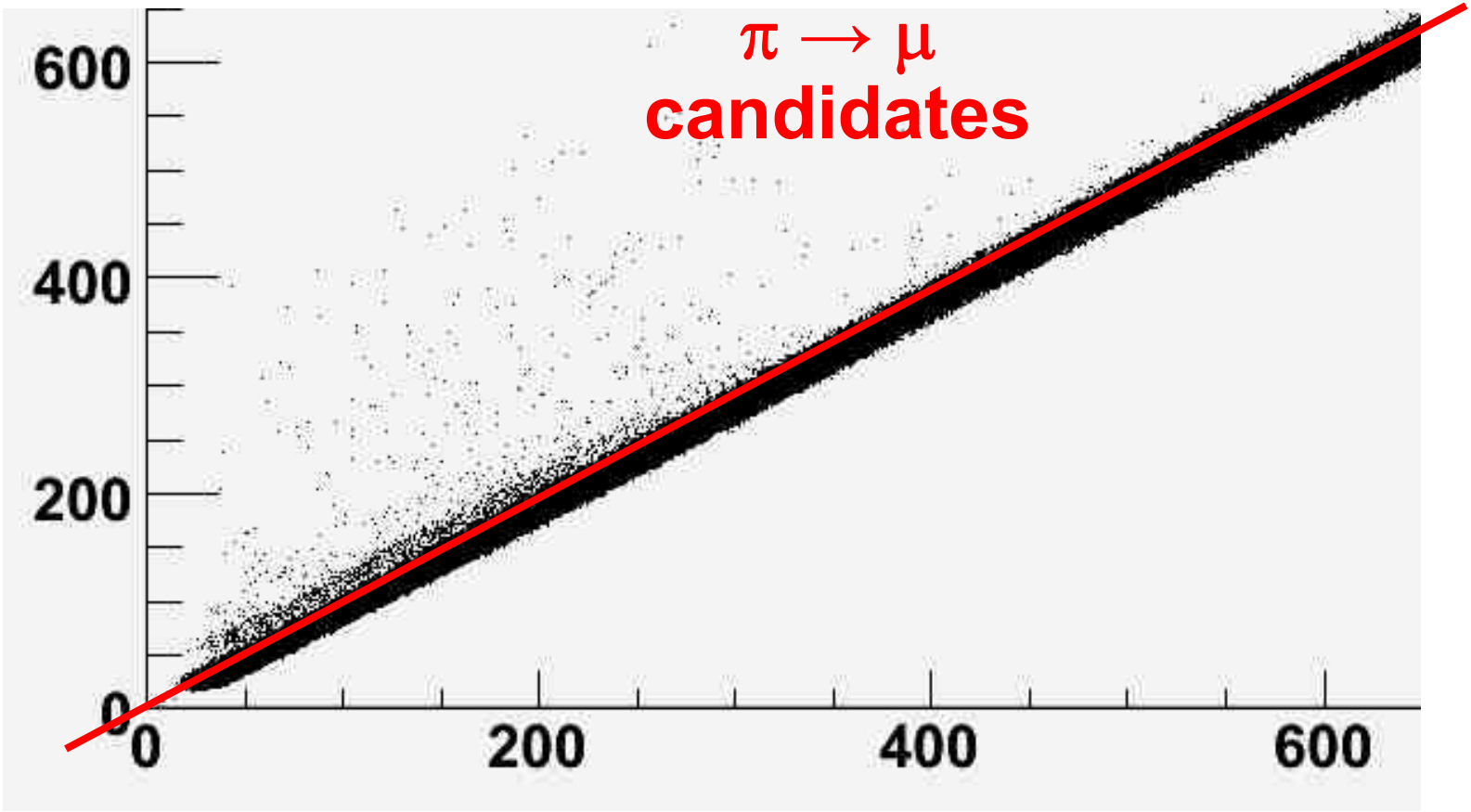
non- π events -- same energy in long/short gates

π events -- +4.12 MeV in long gate

plot of long vs. short will show offset for π events

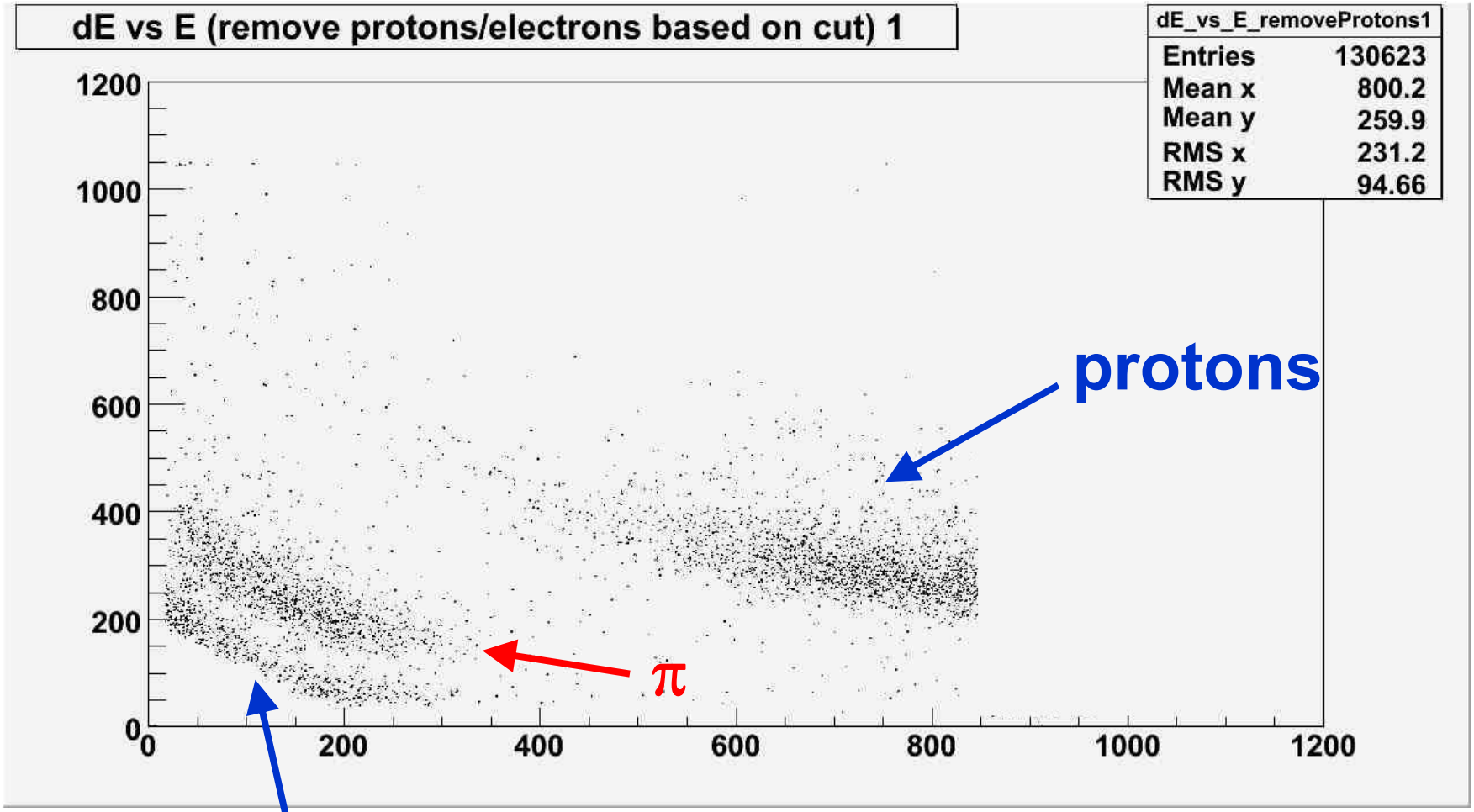
π identification

- π → μ decays now seen



π identification

- select $\pi \rightarrow \mu$ candidates



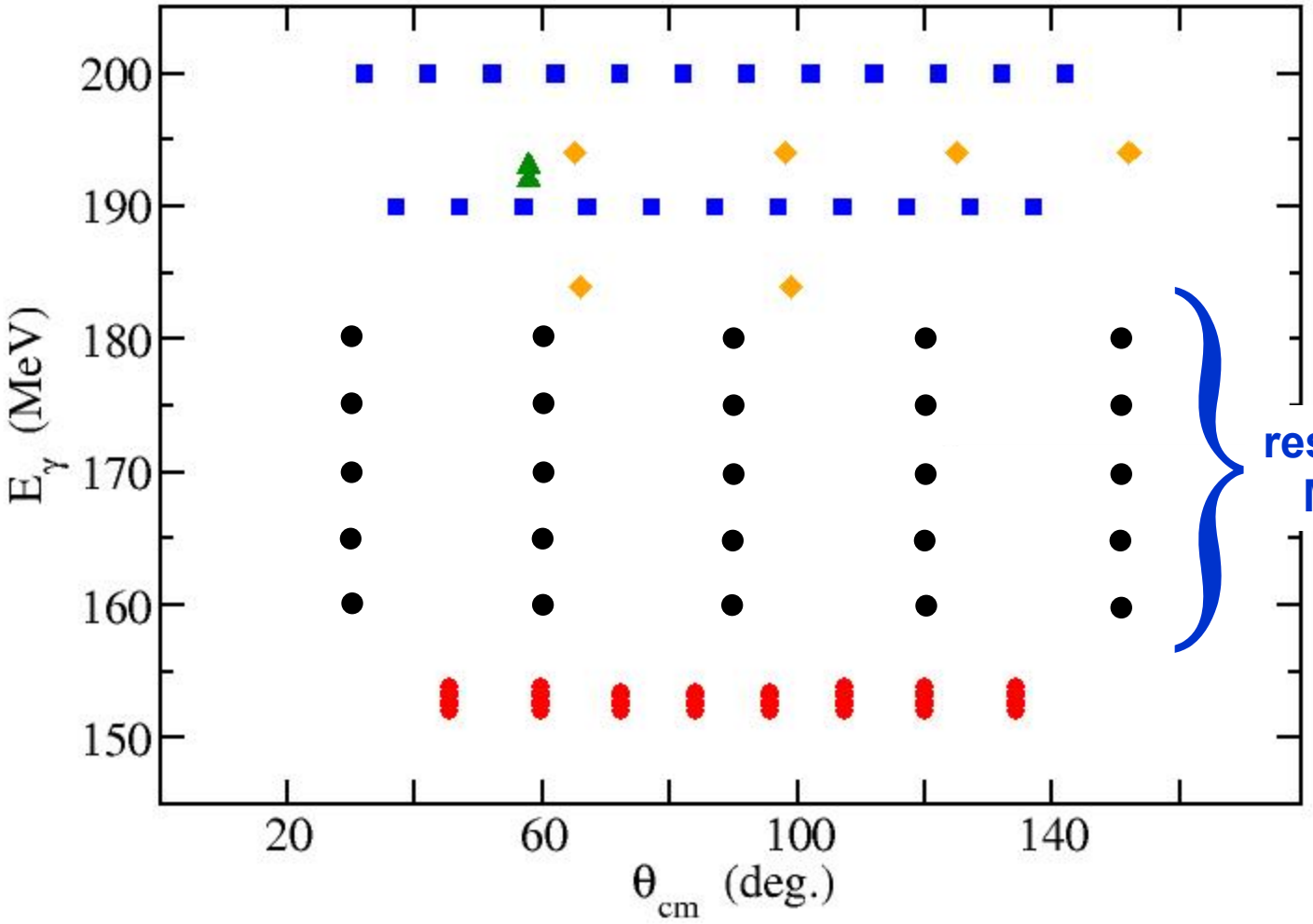
(γ,π^+) program @ MAX-lab

- development work in 2006, 2008
  - new counters
  - check pion identification methods
  - understand tagging efficiency

- 4-weeks production data this summer
  - completed set-up (March, April this year)
  - systems working & tested
  - anticipate ~ 5% statistical error
  - comparable systematic errors (with some work)

(γ,π^+) program @ MAX-lab

anticipated energy/angular coverage



results from MAX-lab