Results from BNL E949 on $K^+ \to \pi^+ \gamma\gamma$

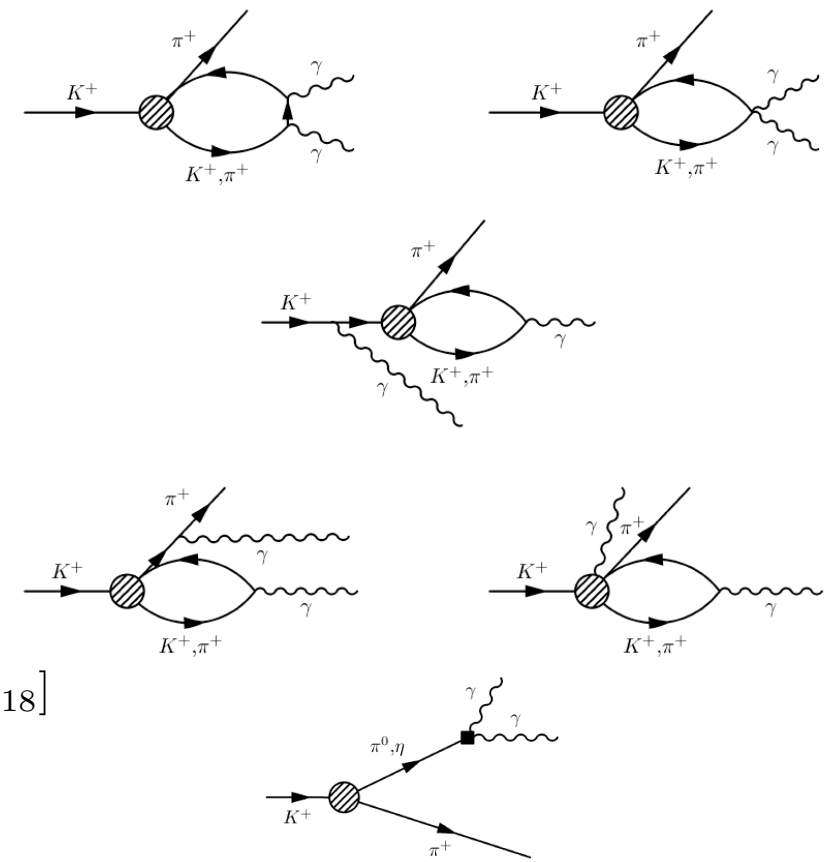
Benji Lewis
University of New Mexico

P. Kitching
Centre for Subatomic Research, University of Alberta
D.A. Bryman
University of British Columbia
B. Bhuyan, I-H. Chiang, M.V. Diwan, J.S. Frank, J.S. Haggerty, D.E. Jaffe, S.H. Kettell, K.K. Li, L.S. Littenberg, G. Redlinger, R.C. Strand and **B. Viren**
Brookhaven National Laboratory (BNL)
P.S. Cooper, E. Ramberg and R.S. Tschirhart
Fermi National Accelerator Laboratory (FNAL)
M. Miyajima and Y. Tamagawa
Fukui University
A. Artamonov, A. Kozjevnikov, **A. Kushnirenko**, L. Landsberg, V. Mukhin, V. Obraztsov, D. Patalakha, S. Petrenko and D. Vavilov
Institute for High Energy Physics (IHEP)
V.V. Anisimovsky,A.P. Ivashkin, M.M. Khabibullin, **A.N. Khotjantsev**, Y.G. Kudenko, O.V. Mineev and **N.V. Yershov**
Institute for Nuclear Research (INR)
S. Kabe, M. Kobayashi, T.K. Komatsubara, **E. Ohashi**, K. Omata, T. Sato, **T. Sekiguchi**, S. Sugimoto, **T. Tsunemi**, Y. Yoshimura and
N. Muramatsu
Japan Atomic Energy Research Institute (JAERI)
T. Fujiwara, **K. Mizouchi**, T. Nomura and N. Sasao
Kyoto University
T. Shinkawa
National Defense Academy of Japan
B. Bassalleck, **B. Lewis** and J. Lowe
University of New Mexico (UNM)
M. Nomachi
Osaka University
T. Nakano
Research Center for Nuclear Physics (RCNP), Osaka University
I.-A. Christidi and M.D. Marx
Stony Brook University
P.C. Bergbusch, E.W. Blackmore, **S. Chen**, **J. Hu**, A . Konaka, J.A. Macdonald, **J. Mildenberger**, T. Numao, J.-M. Poutissou and R. Poutissou
TRIUMF

$K^+ \to \pi^+ \gamma\gamma$

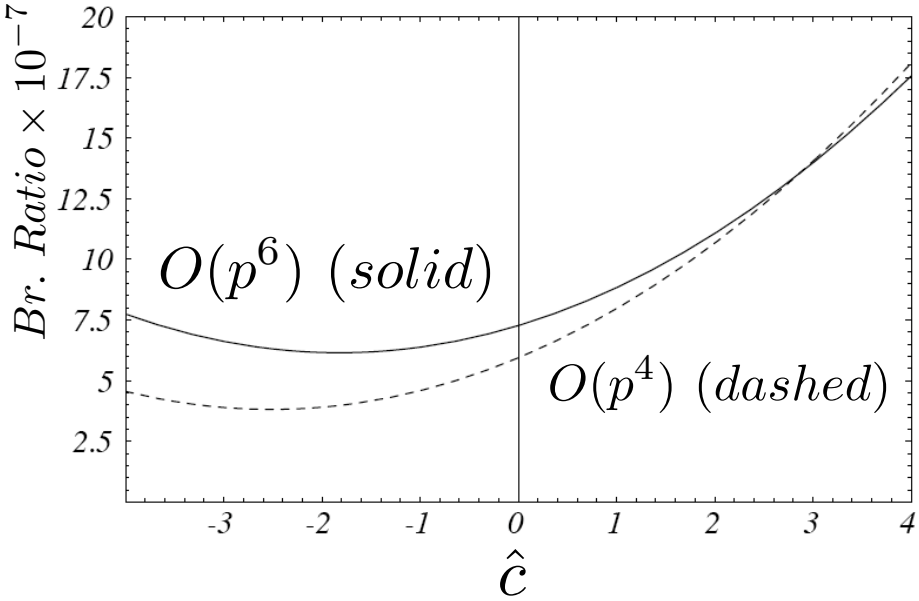
Chiral Perturbation Theory (ChPT)

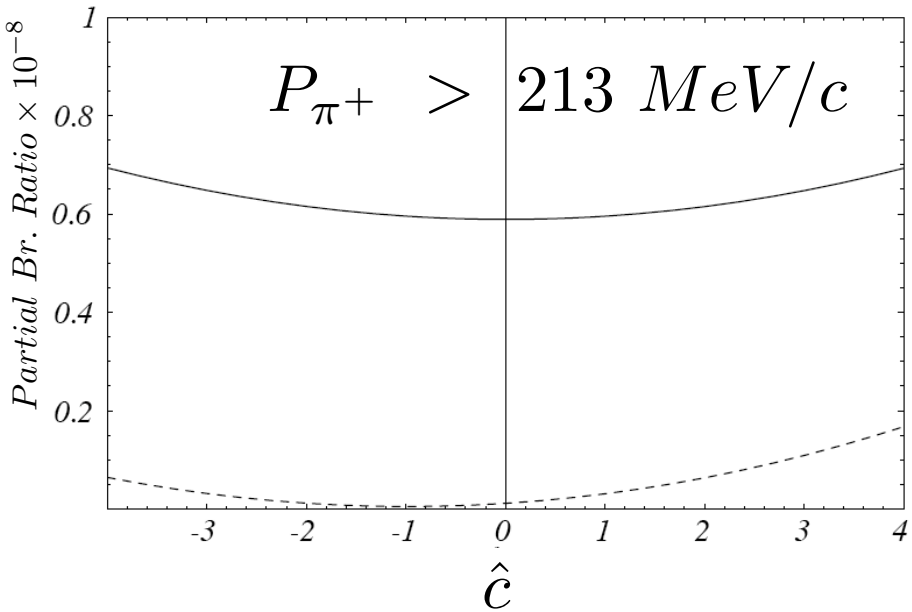
loop diagrams from ChPT for $\mathcal{O}(p^4)$



- no tree level contribution $\mathcal{O}(p^2)$
- $K^+ \to \pi^+\gamma\gamma$ amplitude is determined by $\hat{c}$
- $\hat{c} \equiv \frac{128\pi^2}{3}[3(L_9 + L_{10}) + L_{14} - L_{15} - 2L_{18}]$

Branching Ratio from ChPT





Values obtain from E787 1991

$$\hat{c}_{O(p^4)} = 1.6 \Longrightarrow \mathcal{B} = 4.9 \times 10^{-10}$$
$$\hat{c}_{O(p^6)} = 1.8 \Longrightarrow \mathcal{B} = 6.1 \times 10^{-9}$$

Order of Magnitude different!

E949 Method

K^+ enters E949 Detector

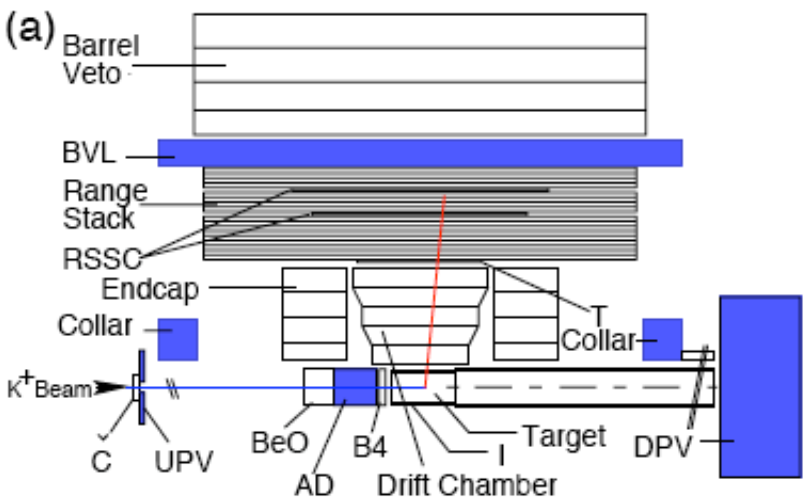
- Cerenkov: K^+/π^+ (PID)
- Active Degrader: slows K^+
- Target: K^+ comes to rest.
- Beam: no other particles (PID)

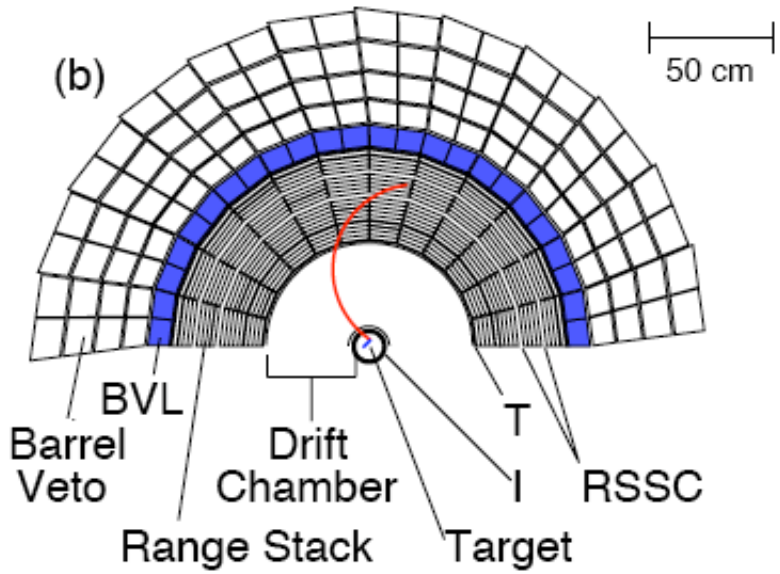
K^+ decays

- Target: 'Delayed Coincidence' between $K^+$and π^+ (Timing)
- Photo Veto: extra E (Veto)
- Target: E,R,T (Kinematics)
- Drift Chamber: P (Kinematics)
- Range Stack: E,R (Kinematics)

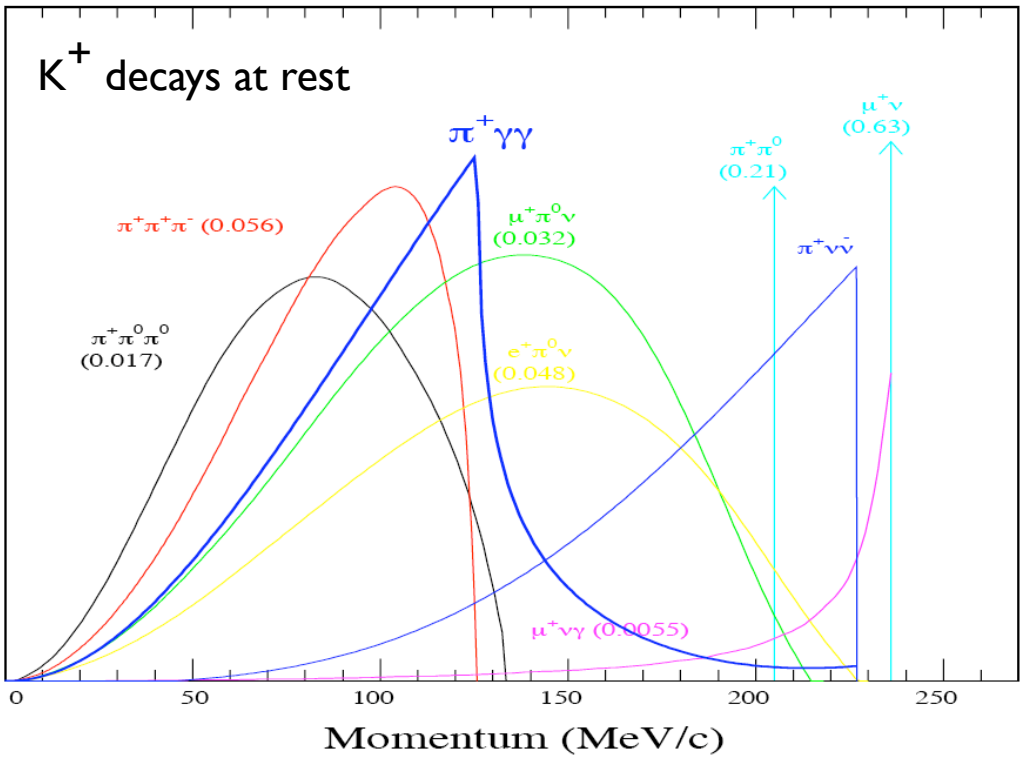
π^+ decays

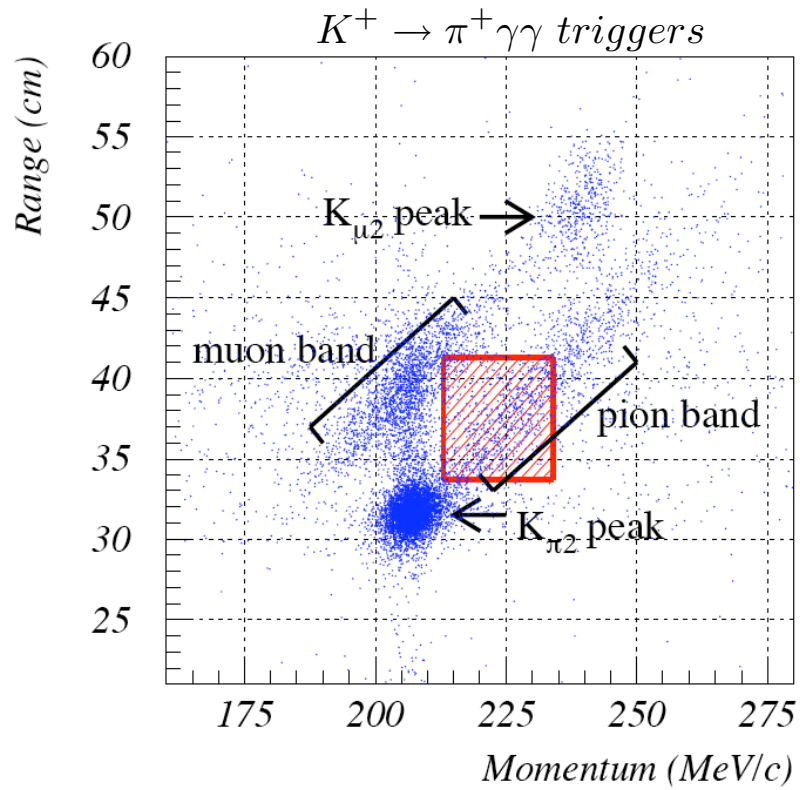
- Range Stack: $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ (PID)





Backgrounds & Trigger Events



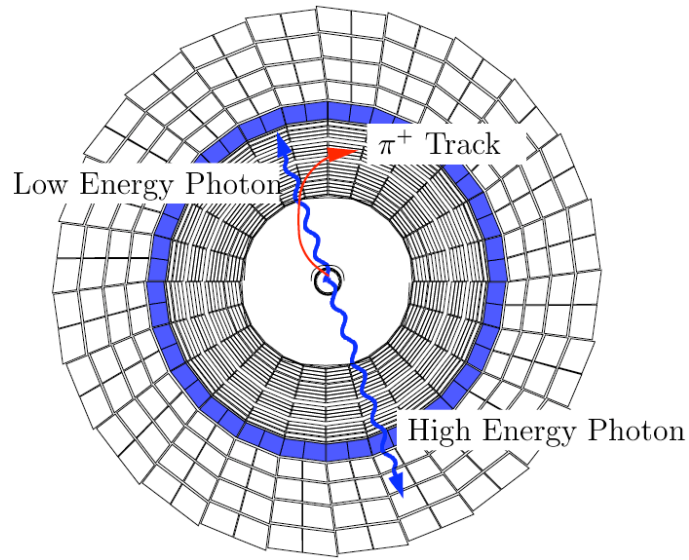


Backgrounds	**Suppression Methods**			
	Kinematics	Photon	Particle ID	Timing
$K^+ \to \pi^+\pi^0$	√	√		
Overlapping Photon	√		√	
Muon	√		√	
Single Beam			√	√
Double Beam				√ √

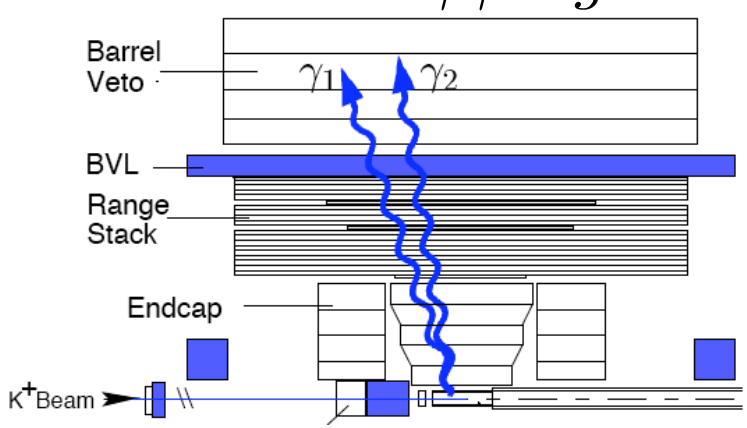
γ Backgrounds

- $K^+ \to \pi^+\pi^0; \pi^0 \to \gamma\gamma$
  $\pi^0 \to \gamma\gamma, 245.6\ MeV$

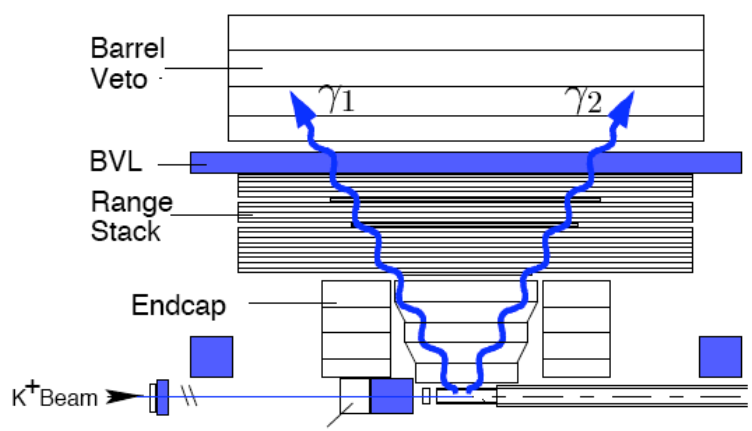
overlapping γ background



$K^+ \to \pi^+\gamma\gamma$ signal

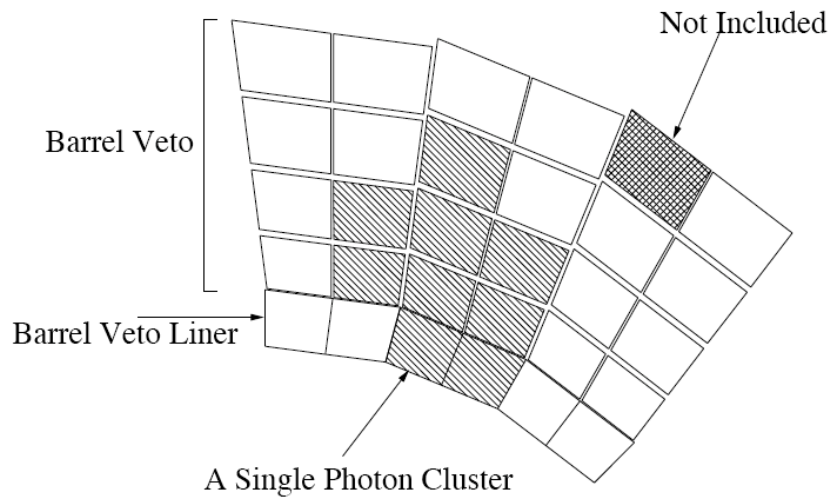


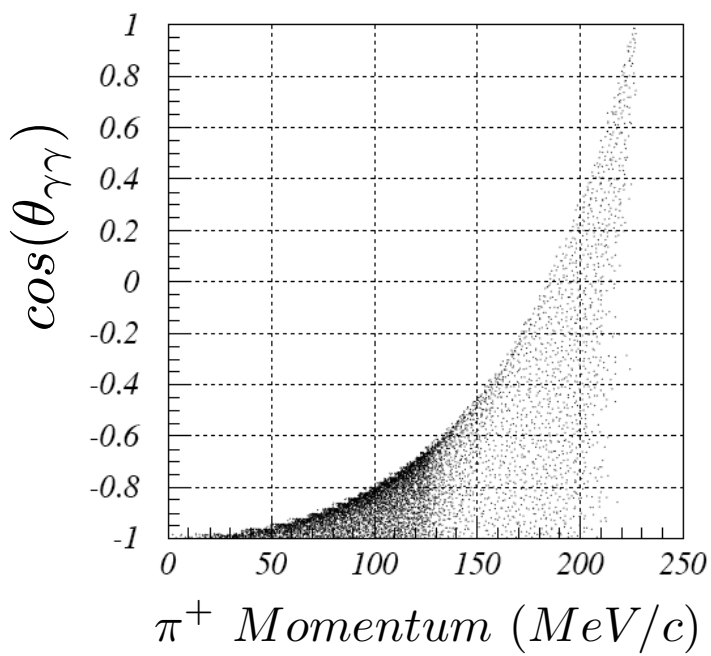
background from $K^+ \to \pi^+\pi^0$

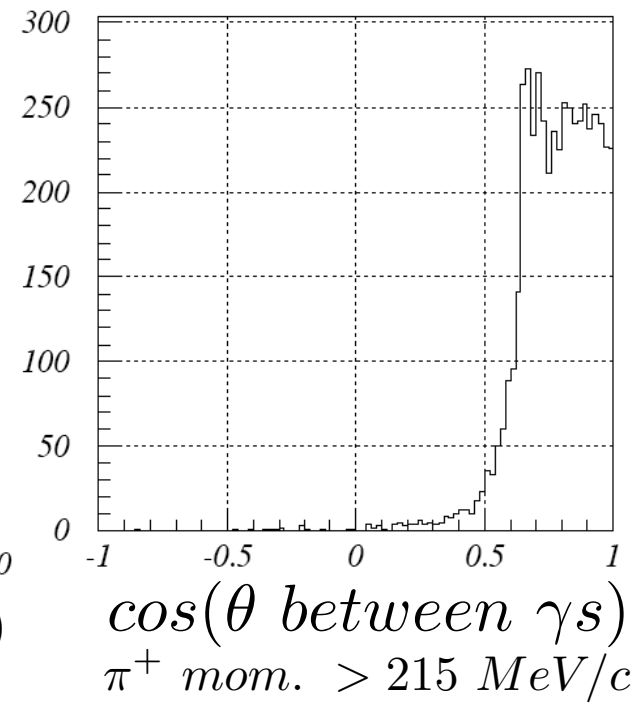


Reconstructing Photons in BV & BVL

- $Trigger\ on\ 1\ or\ 2\ \gamma\ clusters$
- $2\ \gamma \rightarrow 1\ \gamma cluster$
  $for\ high\ mom.\ \pi^+$



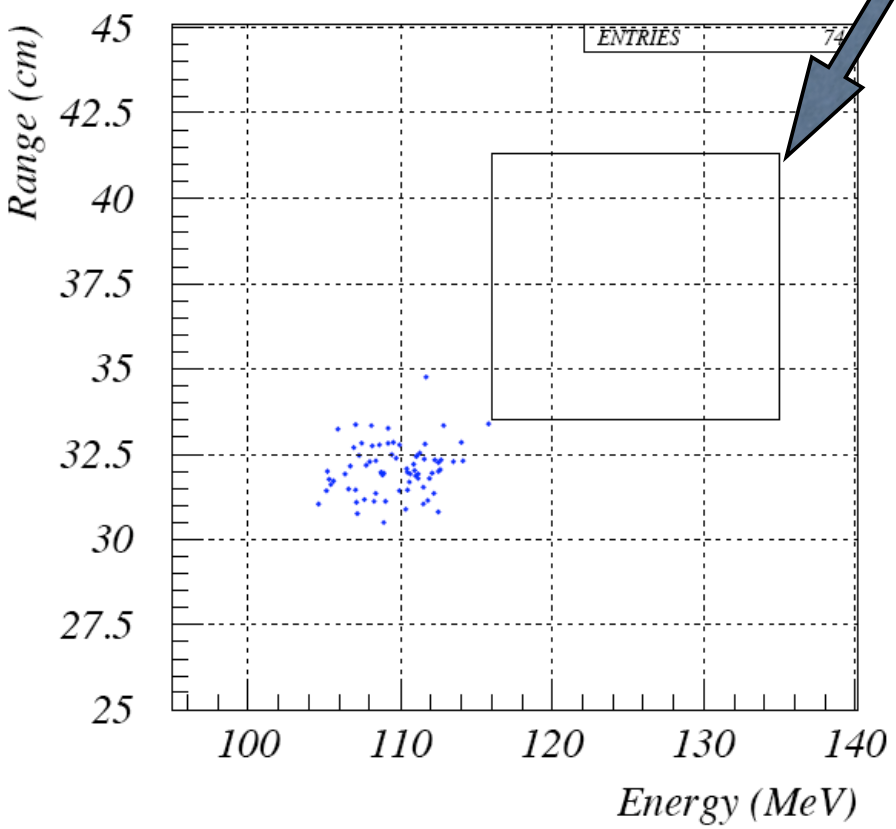




Analysis

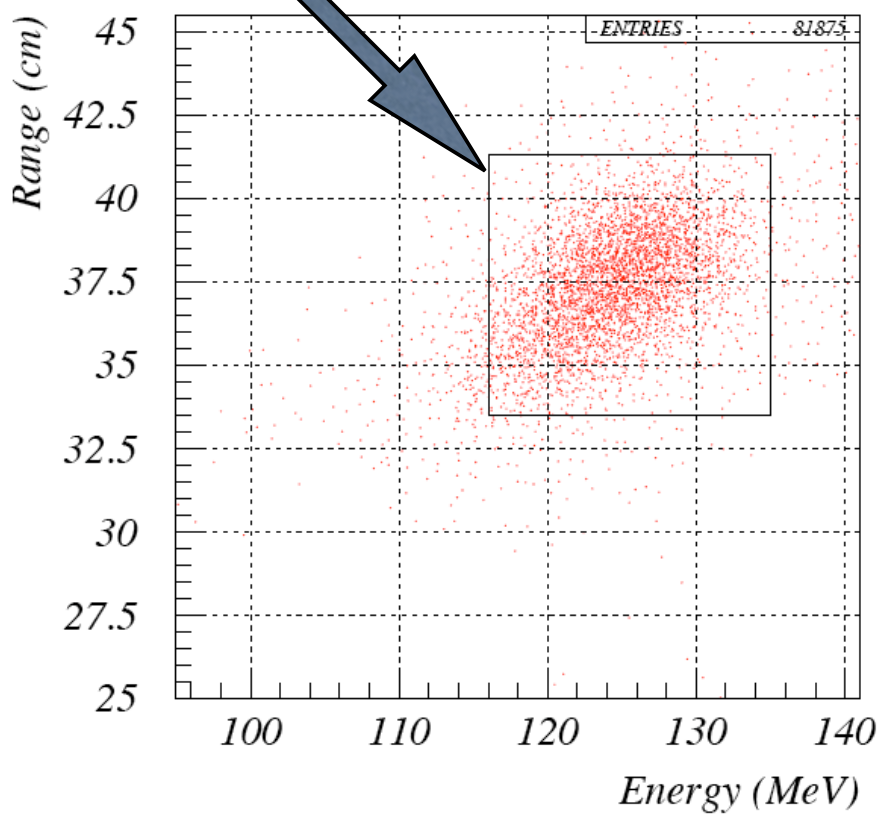
No Events Found

$K^+ \to \pi^+ \gamma\gamma$
Signal Region



Surviving events

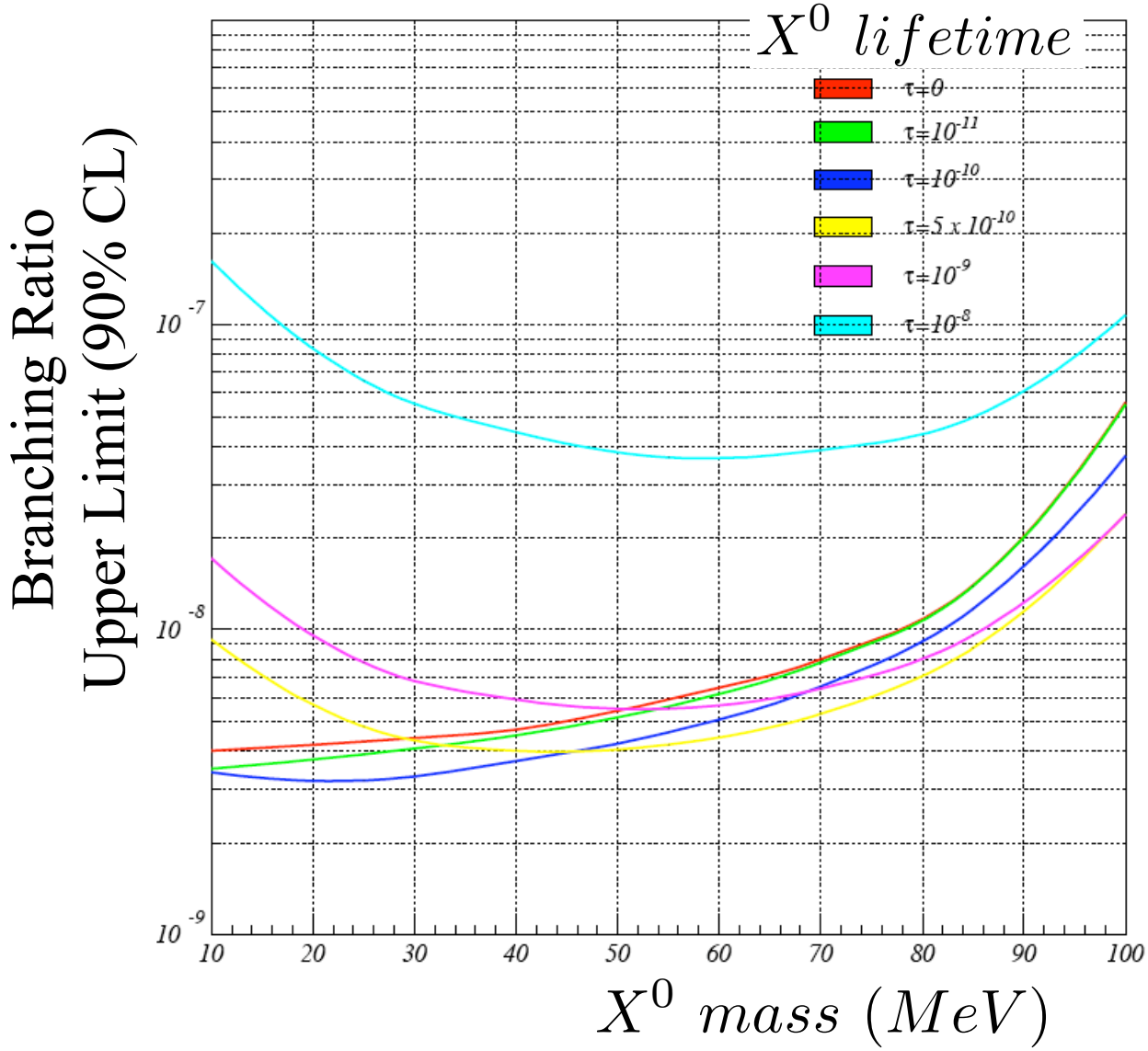
All cuts applied



Simulated distribution

$\hat{c} = 1.8$ unitarity corrections

$$K^+ \to \pi^+ X^0, X^0 \to \gamma\gamma$$



Conclusions

$P_{\pi^+} \; > \; 213 \; MeV/c$

$Below \; K^+ \to \pi^+\pi^0 \; peak \; (100MeV/c < P_{\pi^2} < 180MeV/c)$

$$\mathcal{B}(K^+ \to \pi^+\gamma\gamma) = [6.0 \pm 1.5 \pm 0.7] \times 10^{-7}$$

$Above \; K^+ \to \pi^+\pi^0 \; peak$

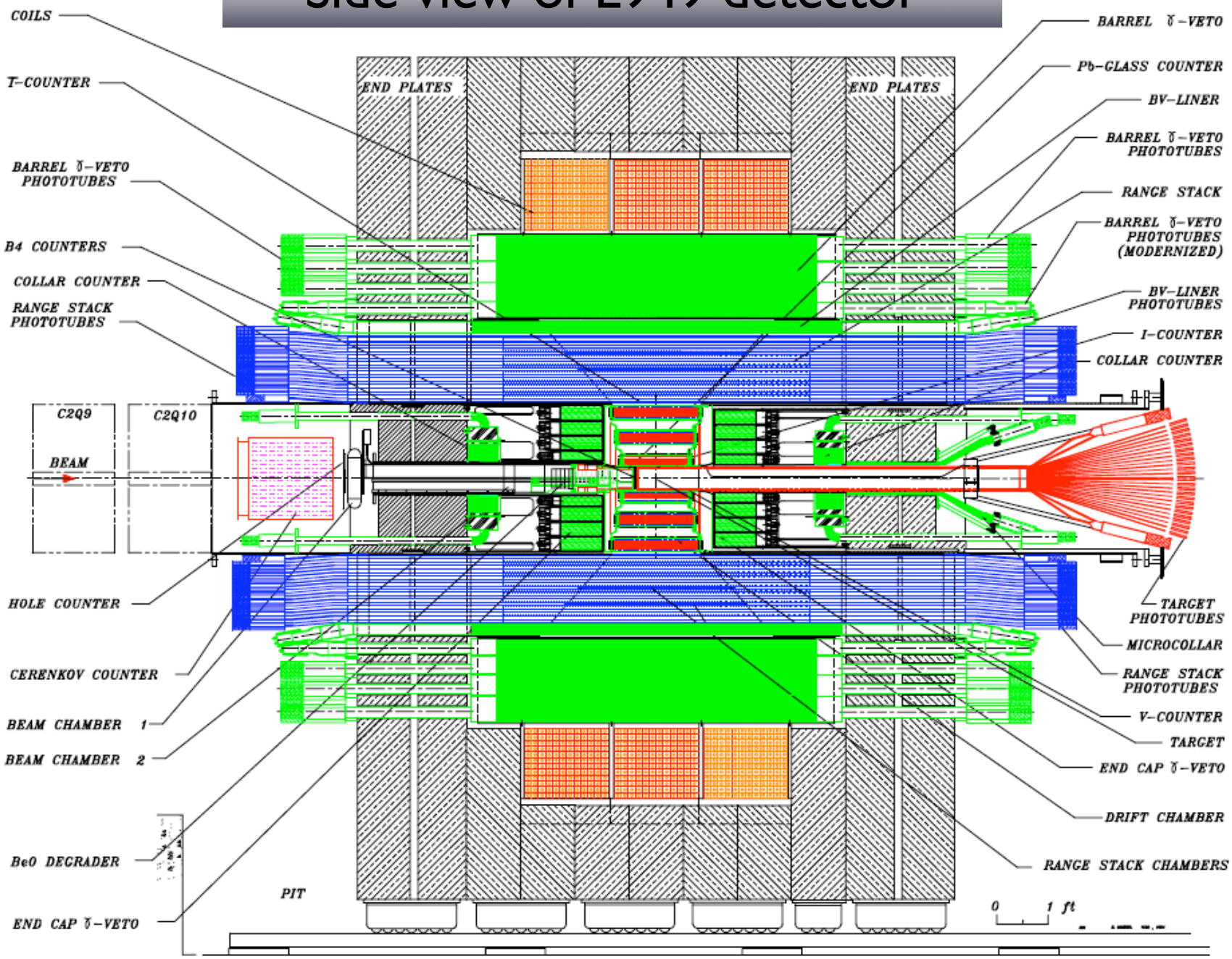
$$\mathcal{B}(K^+ \to \pi^+\gamma\gamma) \; < \; 5.0 \times 10^{-7}$$

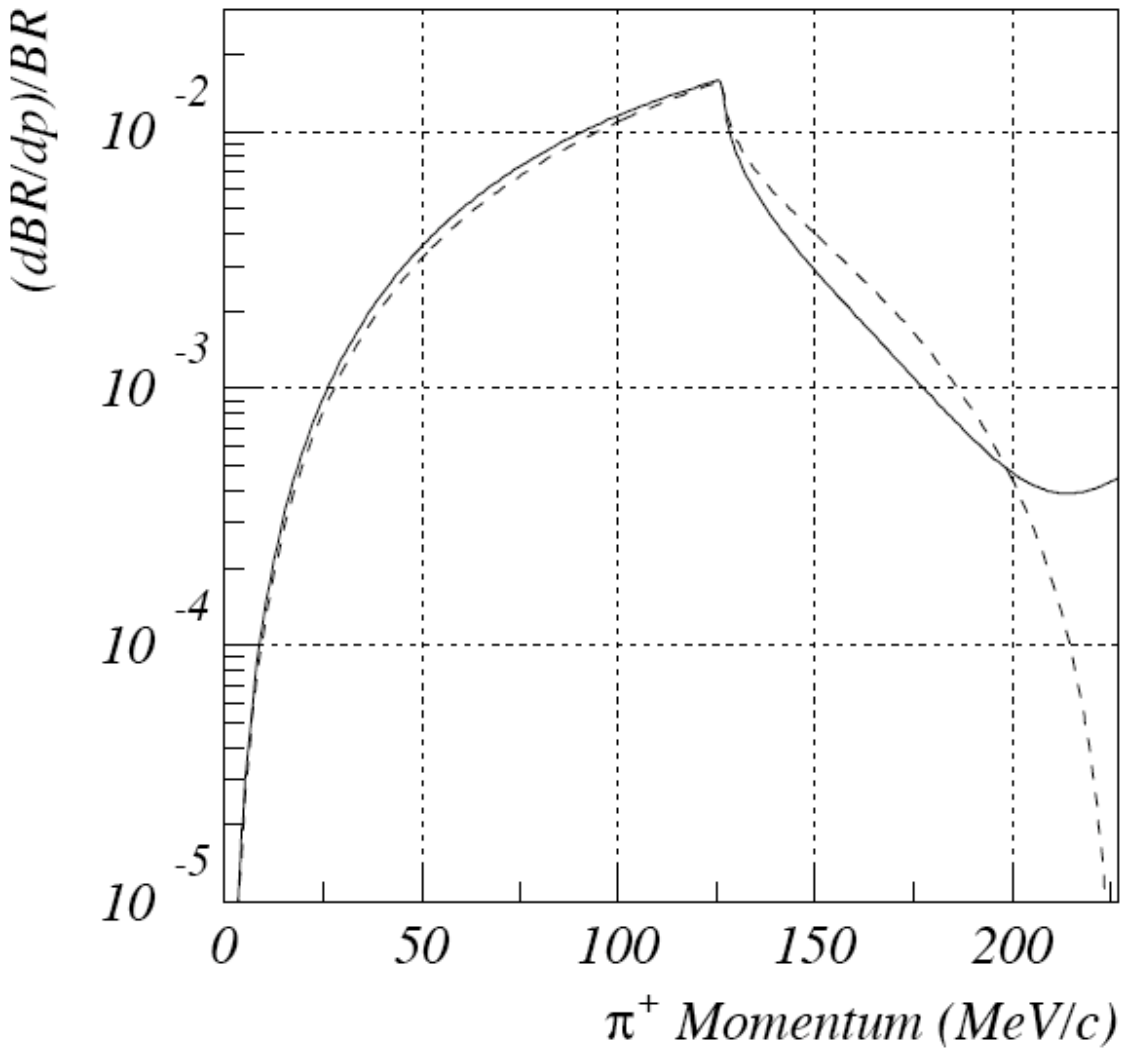
$\hat{c} = 1.8 \pm 0.6$

$$\hat{c}_{O(p^6)} = 1.8 \Longrightarrow \mathcal{B} \; = \; 6.1 \times 10^{-9}$$
$$\hat{c}_{O(p^4)} = 1.6 \Longrightarrow \mathcal{B} \; = \; 4.9 \times 10^{-10}$$

Extras

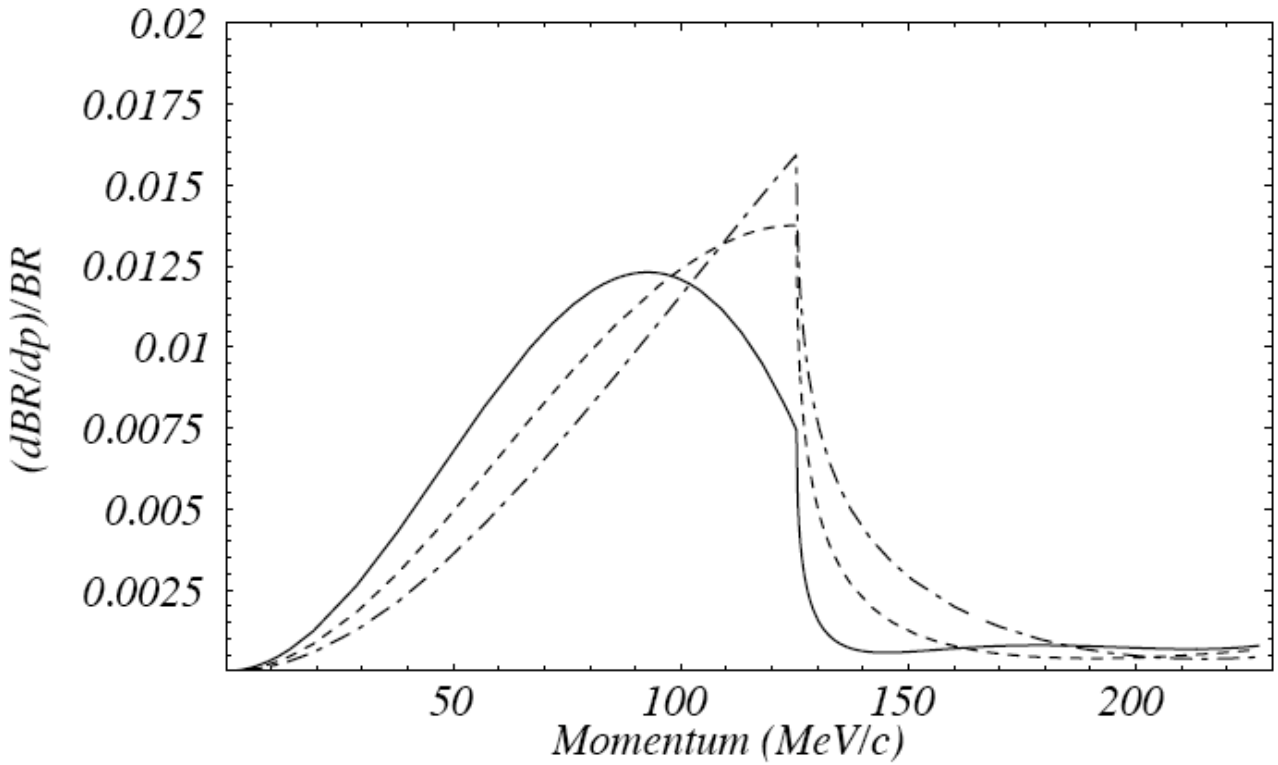
Side view of E949 detector




(dBR/dp)/BR
10 -2
10 -3
10 -4
10 -5
0
50
100
150
200
π+ Momentum (MeV/c)

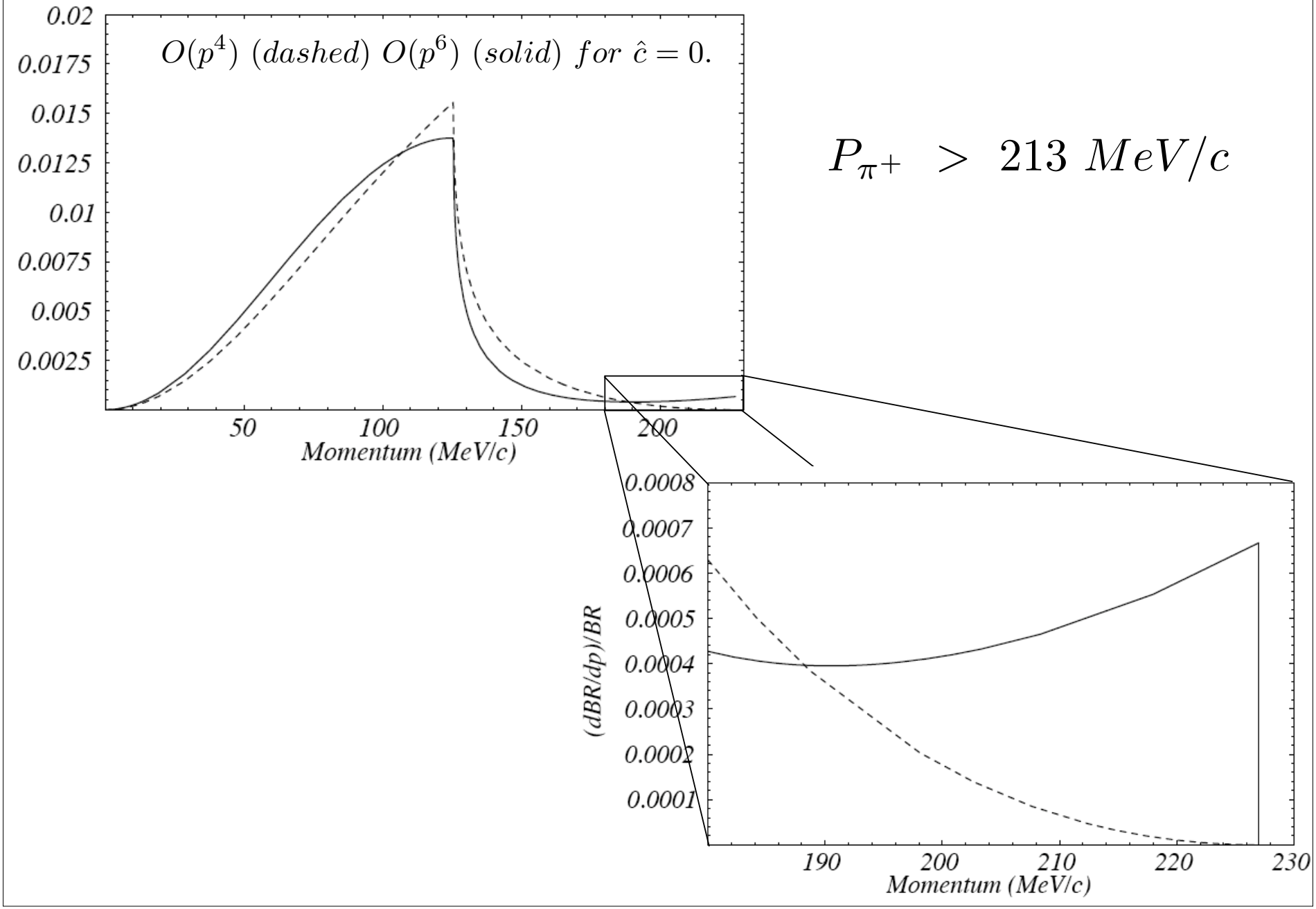
Differential Branching Ratio

$$ChPT\ with\ O(p^4)$$



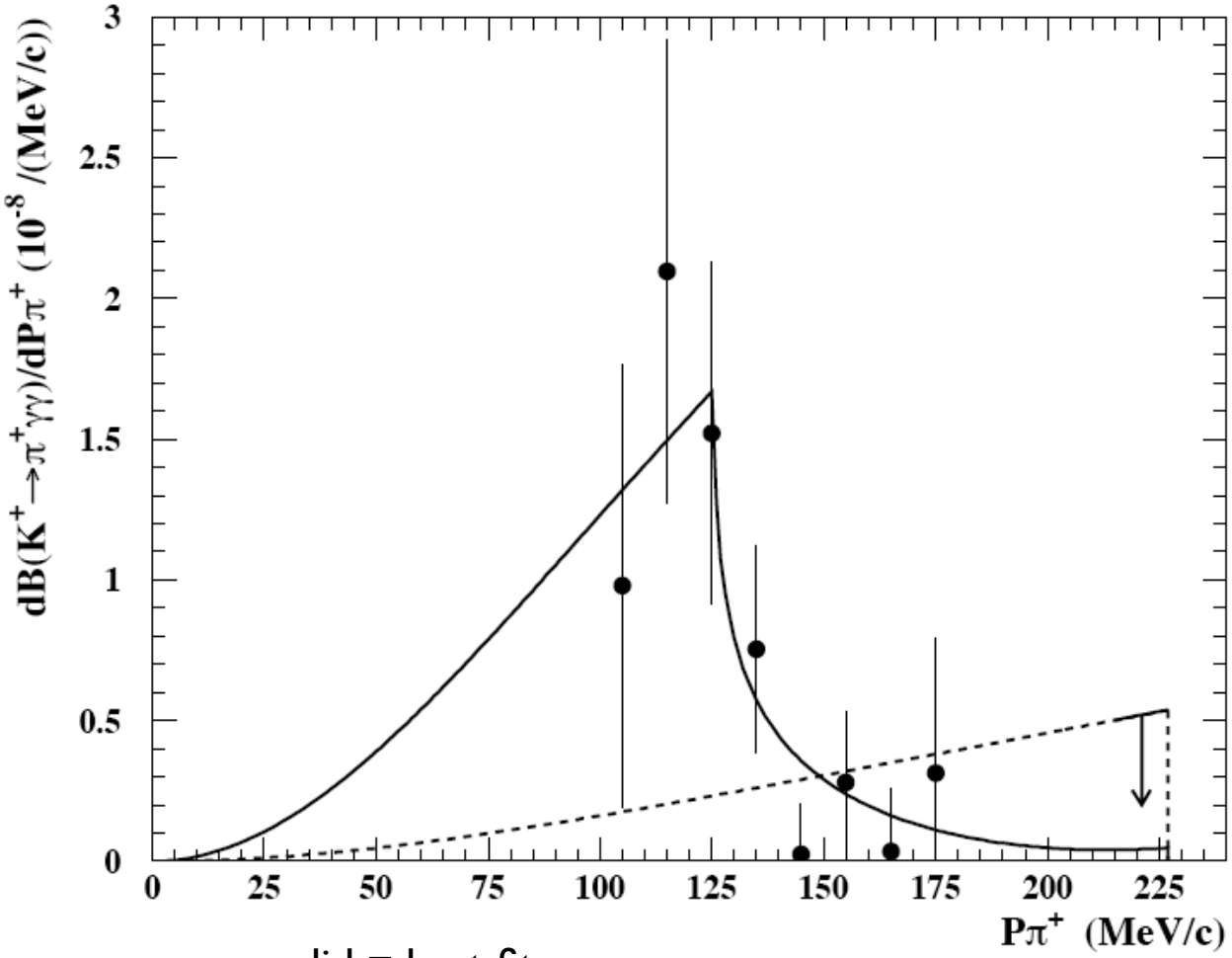
$$\hat{c} = -2\ (solid), \hat{c} = 0\ (dashed), \hat{c} = 2\ (dot - dashed)$$

π^+ Momentum Spectrum



$$P_{\pi^+} > 213\ MeV/c$$

π^+ Momentum Spectrum for E787



solid = best fit,
dashed = phase-space distribution