Charged Pion Polarizability Measured in $\gamma\gamma \rightarrow \pi^+\pi^-$: The Hall D CPP Experiment

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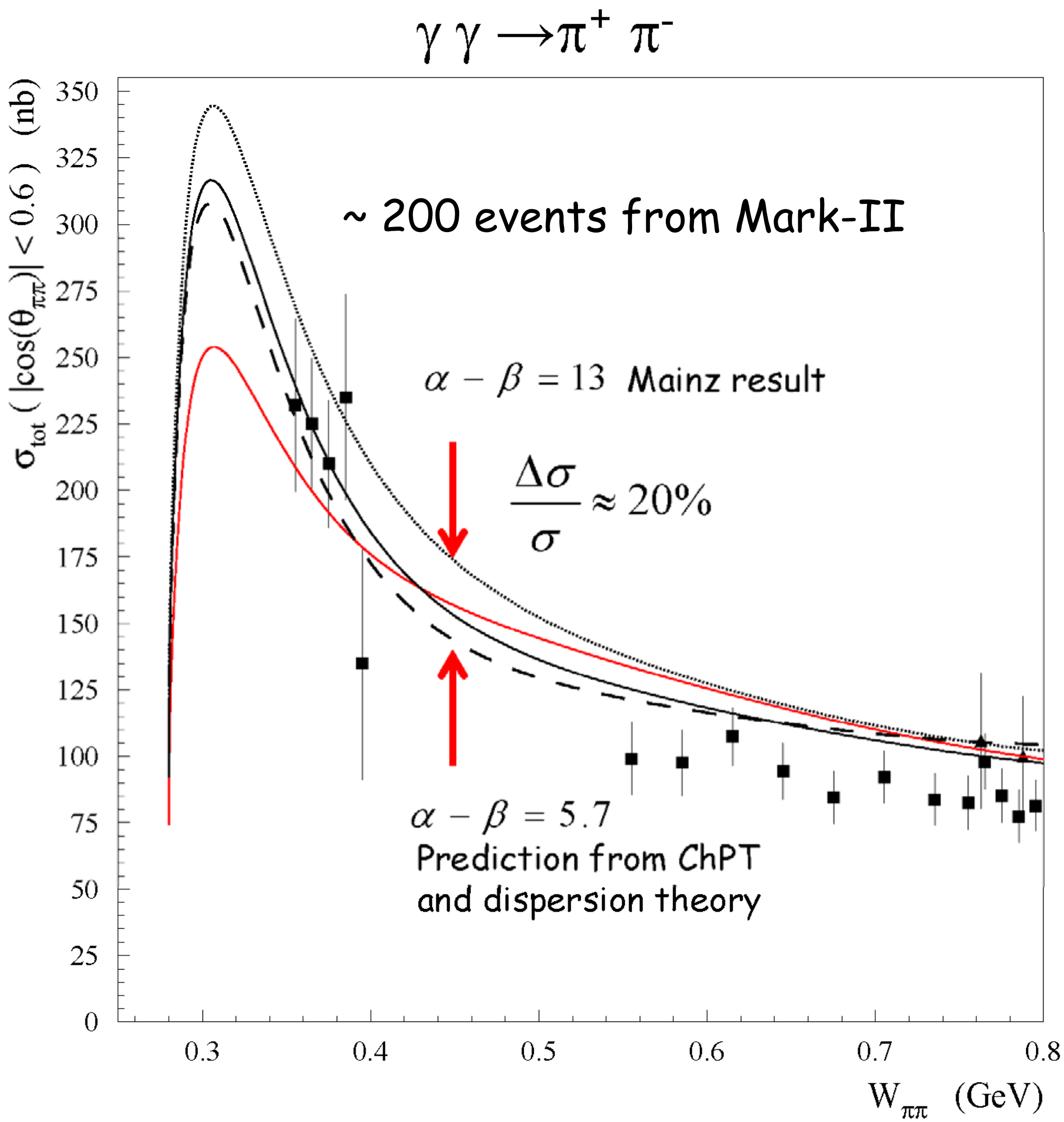
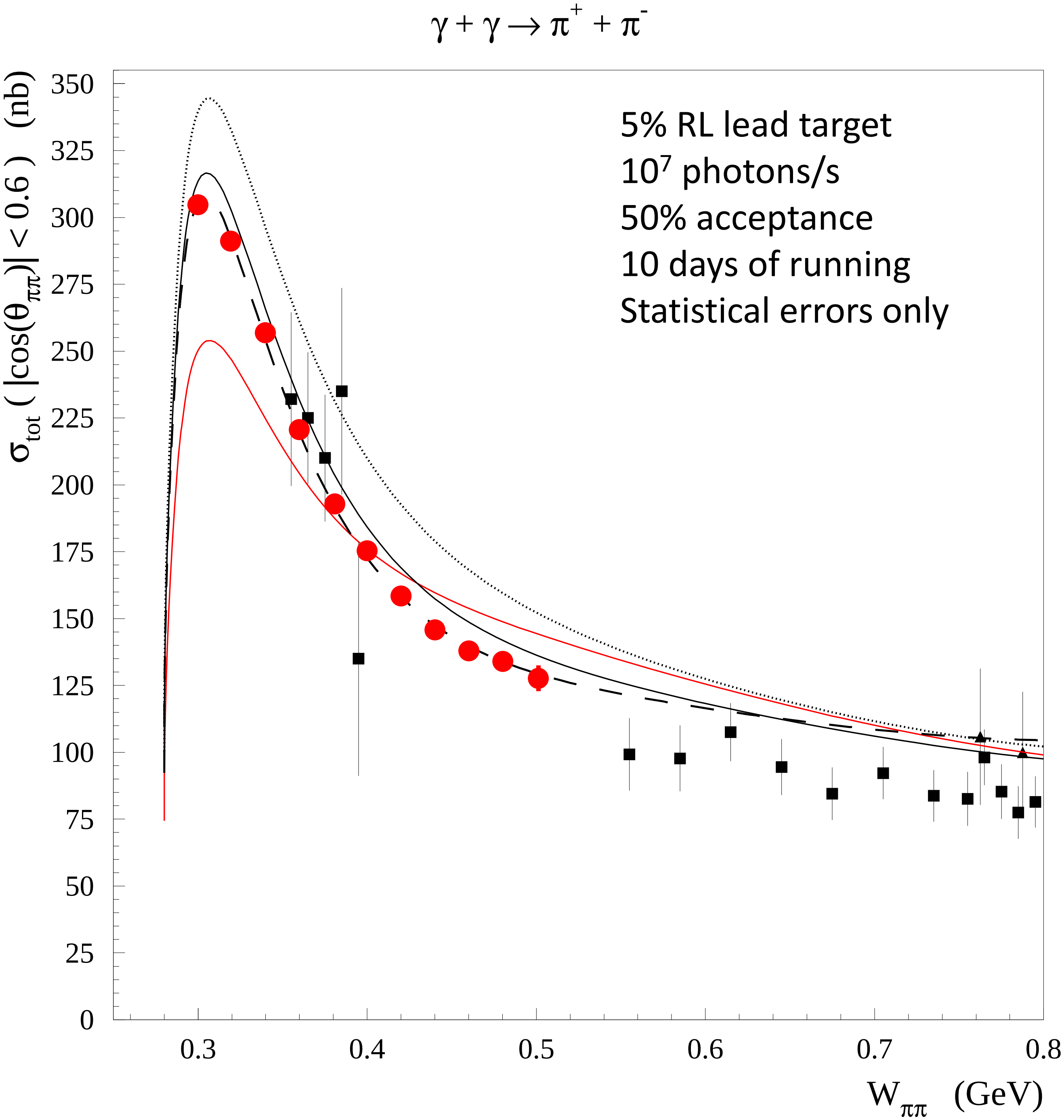


γ γ →π+ π-
~ 200 events from Mark-II
α − β = 13 Mainz result
Δσ/σ ≈ 20%
α − β = 5.7
Prediction from ChPT
and dispersion theory
σtot (|cos(θππ)| < 0.6) (nb)
Wππ (GeV)



$\gamma + \gamma \rightarrow \pi^+ + \pi^-$
5% RL lead target
10^7 photons/s
50% acceptance
10 days of running
Statistical errors only
σ_{tot} ($|\cos(\theta_{\pi\pi})| < 0.6$) (nb)
$W_{\pi\pi}$ (GeV)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
0.3
0.4
0.5
0.6
0.7
0.8

Measure $\gamma A \to \pi^+\pi^- A$ cross sections relative to $\gamma A \to \mu^+\mu^- A$

Theory for e^+e^- pair production: amplitudes in order of decreasing importance :

(i) Bethe-Heitler pair production on the nucleus with atomic screening,

(ii) pair production on atomic electrons

(iii) QED radiative corrections of order α/π with respect to the dominant Bethe-Heitler term,

(iv) nuclear incoherent production on protons

(v) virtual Compton scattering, $\gamma A \to \gamma^* A \to e^+e^- A$

PRIMEX: experimental and theoretical cross sections agree within the experimental errors of ±0.58 (stat.) % ± 1.13 (sys.) % for single-arm $e^+(e^-)$ production on ^{12}C.

Measure $\gamma A \to \pi^+\pi^- A$ cross sections relative to $\gamma A \to \mu^+\mu^- A$

Theory for $\mu^+\mu^-$ pair production when the pair is detected :

(i) Bethe-Heitler pair production on the nucleus with atomic screening,

(ii) ~~pair production on atomic electrons~~

(iii) ~~QED radiative corrections of order α/π with respect to the dominant Bethe-Heitler term,~~

(iv) ~~nuclear incoherent production on protons~~

(v) virtual Compton scattering, $\gamma A \to \gamma^* A \to \mu^+\mu^- A$

- Want $Z\alpha$ to be not so large for doing Coulomb corrections

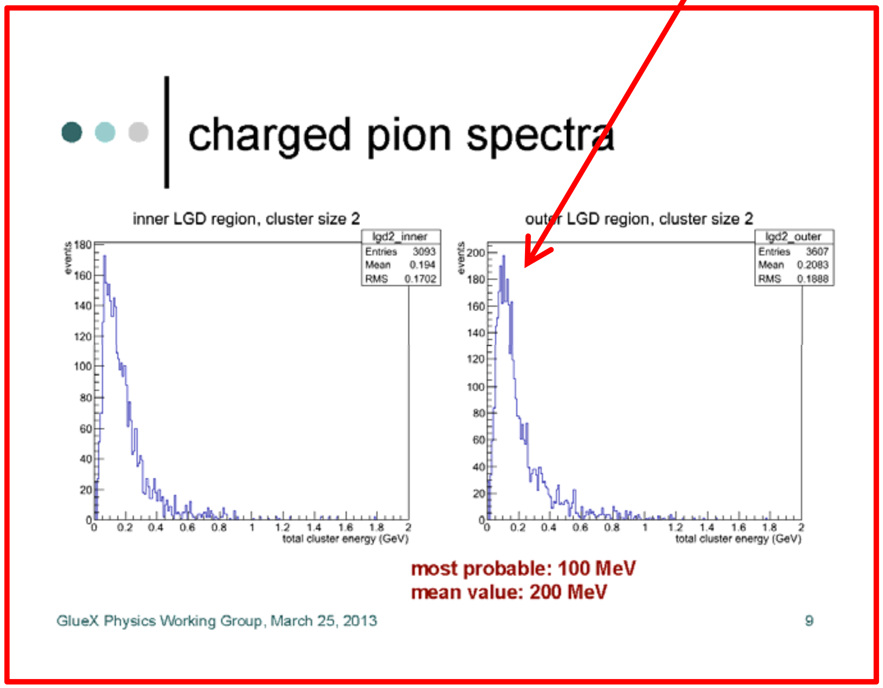
Z	$Z\alpha$
Carbon	.044
Silicon	.10
Iron	.20
lead	.60

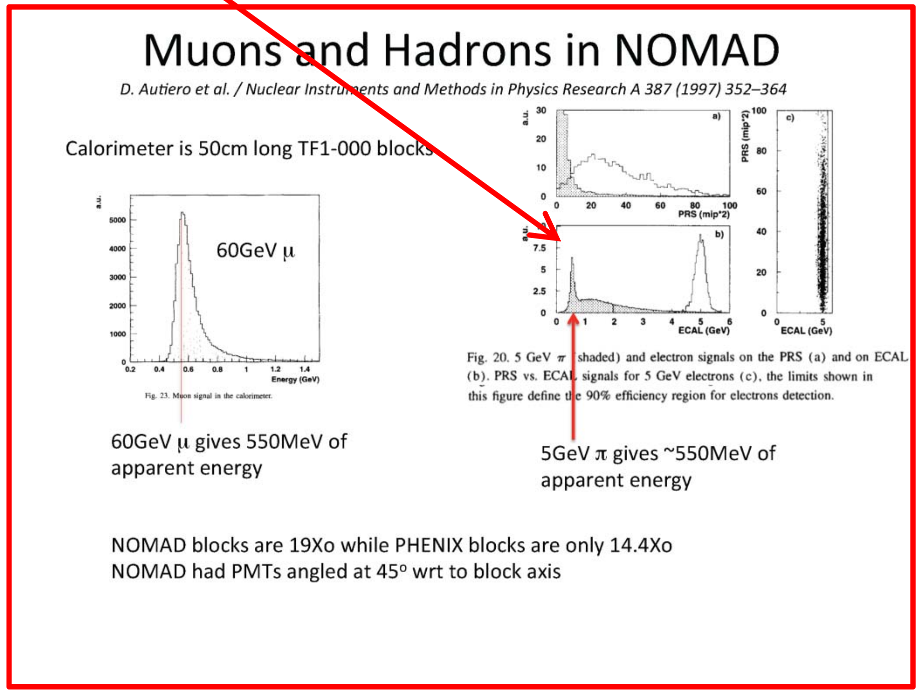
- Azimuthal distribution of $\mu^+\mu^-$ system† measures photon polarization

$$\frac{d\sigma}{d\Omega_{\mu\mu}} \propto \left|(\vec{\varepsilon}\times\vec{q})\cdot\vec{q}\right|^2 \approx \cos^2\phi_{\mu\mu} = 1+\cos 2\phi_{\mu\mu}$$

† S. Bakmaev, et al., Phys. Lett. B 660 (2008) 494.

How efficient is FCAL for charged pions?

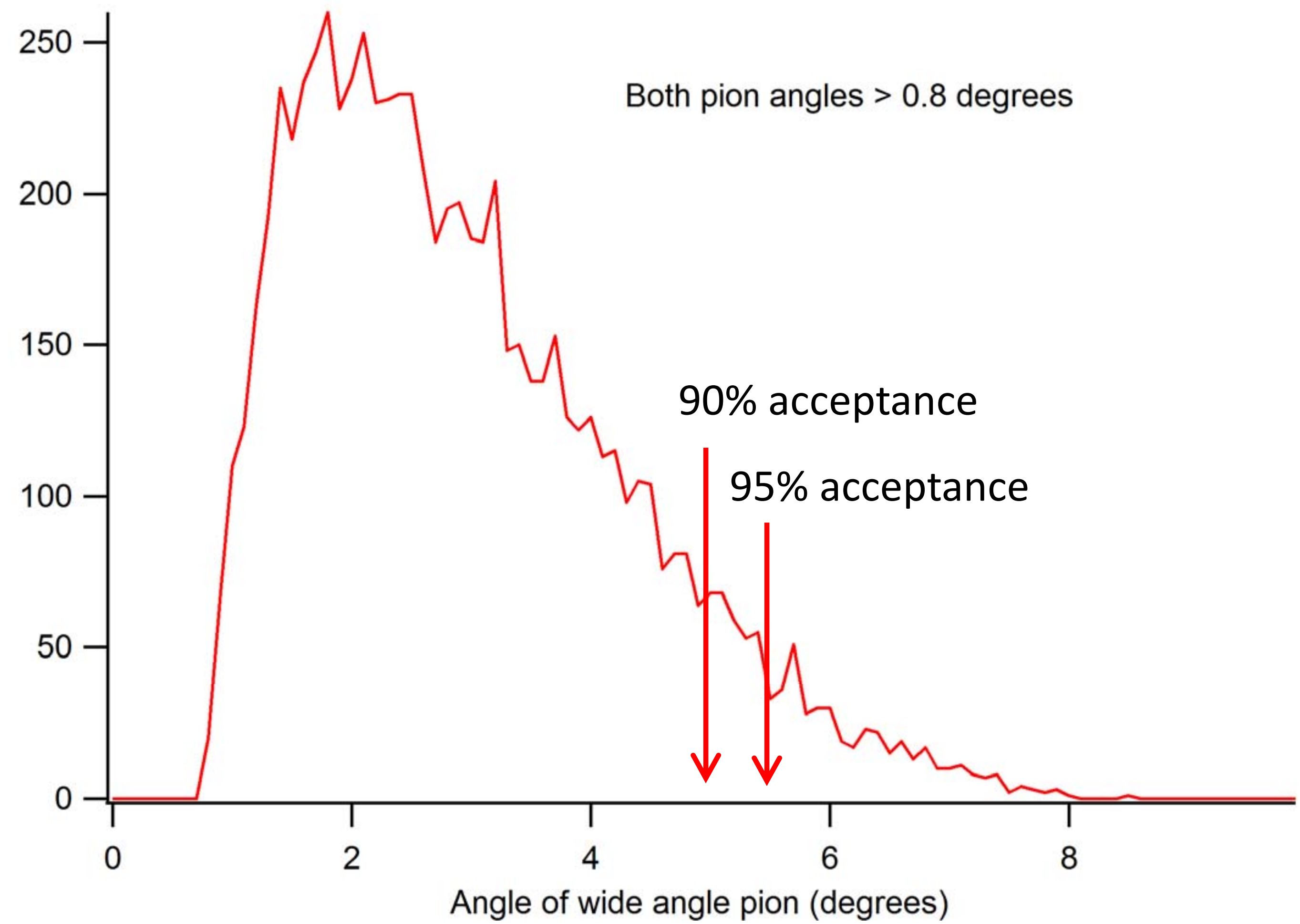


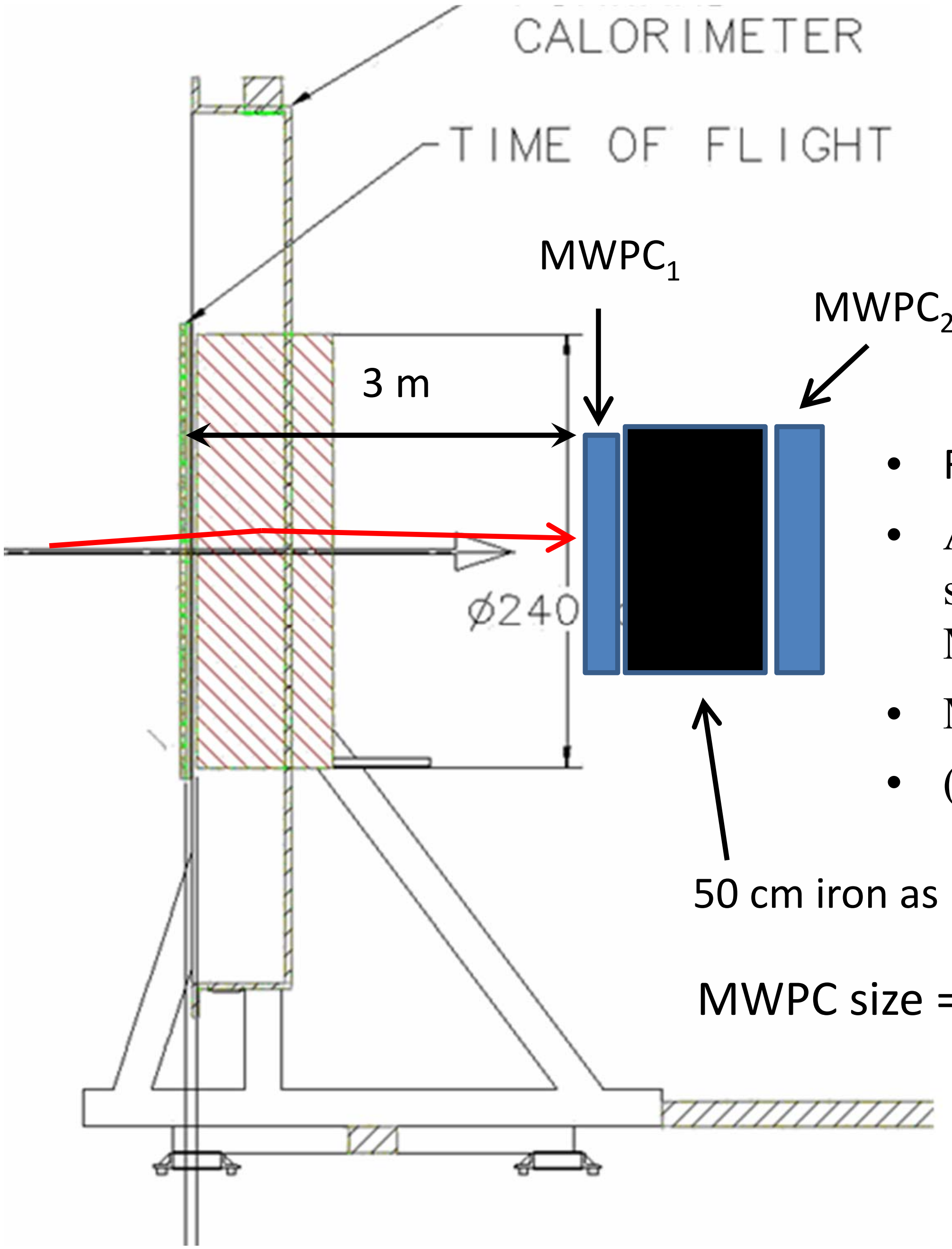


- Construct a relatively simple detector backing FCAL to augment charged pion detection

Questions:

- Can we use FCAL to detect charged pions with reliable efficiency?
- How big do our detectors need to be to detect muons (pions)?

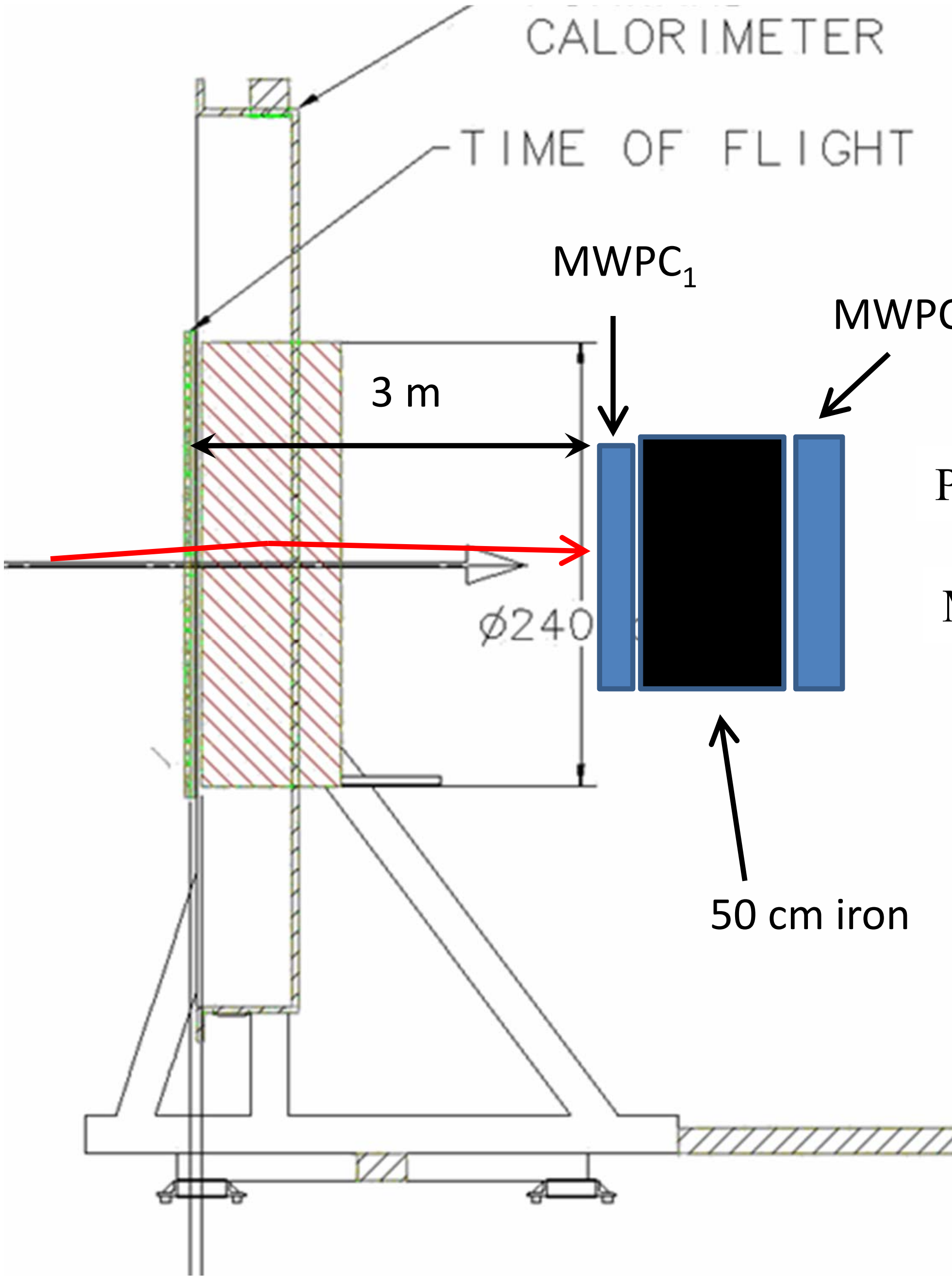




- FCAL efficiency for pions ~ 90%?
- Assume MWPC has u,v planes with cathode strip readout, each plane is 95% efficient for MIP
- MWPC efficiency for MIP $=1-.05^2 = 99.8\%$
- (FCAL + MWPC$_1$) efficiency = 100.0%

50 cm iron as hadron filter, approx. 5 λ_I in total

MWPC size = 2 x (6.2 + 3) x tan(5.5°) = 1.8 m



$$\text{Pion signal} = TOF \cdot (FCAL + MWPC_1) \cdot \overline{MWPC_2}$$

$$\text{Muon signal} = TOF \cdot (FCAL + MWPC_1) \cdot MWPC_2$$

Correction factors and uncertainties	Comments	Uncertainty in correction factor, $\Delta\sigma(\gamma\gamma\rightarrow\pi\pi)$
Statistical error in $M_{\gamma\gamma}$ bins @ 300, 400 and 500 MeV	5% RL lead target, 10^7 photons/s, 50% acceptance, 10 days of running	1.2, 1.7, and 3.5%
(target thickness)·(photon flux)·(tracking eff.)·(trigger eff.)·(DT correction)	Normalize to $\sigma(\gamma A\rightarrow\mu^+\mu^- A)$ cross sections. Theoretical uncertainty estimated at 1%	1% (Est)
ρ^0 background	Under study	TBD
$\mu^+\mu^-$ background in pion signal is 1.3%	u,v planes with cathode strip readout, each 95% efficient, 5:1 muon to pion ratio. Measure inefficiency with $\mu^+\mu^-$ events, subtract muon from pion yield	Small compared to 1.3%
98% efficiency for pion pair identification	Either pion punches through iron absorber and registers as muon, 2%. Measure this probability using $\gamma A\rightarrow\rho A$ events.	Small compared to 2%
One of the pions decays in flight, ~ 8%	Biggest uncertainty is probably from a pion decaying after the FDC's, resulting in a relatively low energy muon that stops in the iron absorber or misses $MWPC_2$; would look like pion track.	TBD
accidental subtraction	Under study	TBD

Task list:

- Complete analysis of systematic errors in error table
- Influence of ρ^0 background on experimental errors $\rightarrow$ running times
- Work through parameters of the muon system
- Submit draft proposal to collaboration mid-week