π^0 Angular Distribution and Excitation Function

February 02, 2005

Jan Stillings

Overview

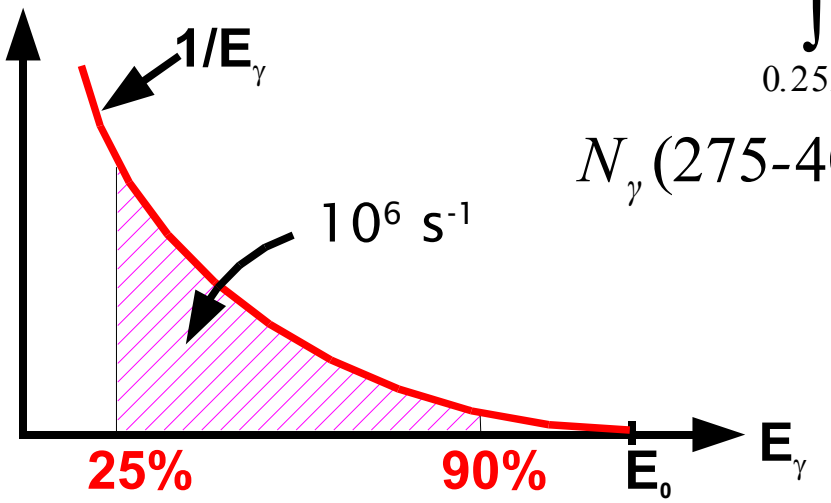
- Estimation of π^0 count rate
- Kinematics and detector setup
- π^0 identification
- Excitation function
- Angular distribution
- Summary

Estimation of π^0 count rate

$$N_\pi = N_{beam}(E_\gamma = 340 \pm ...\text{MeV}) \cdot \frac{d\sigma}{d\Omega} \cdot \Delta\Omega \cdot \varepsilon_{det} \cdot n_p^{target} \cdot \varepsilon_{tag}$$

π_0-rate

- Photon flux:



$$\int_{0.25E_0}^{0.9E_0} \frac{dN}{dE} dE = 10^6 = N_0 \ln(0.9/0.25)$$

$7.8 \cdot 10^5\,\text{s}^{-1}$

$$N_\gamma(275\text{-}407\,\text{MeV}) = N_0 \ln(0.32/0.22)$$

$$= 3.7 \cdot 10^5\,\text{s}^{-1}$$

at E_0 = 1.26 GeV

Estimation of π^0 count rate

- Cross section

$$\gamma + p \rightarrow p + \pi^0 \qquad \frac{d\sigma}{d\Omega}\left(\theta^{CM} = 90°\right) = 28.5\,\mu\text{barn/sr} \;@\; W = 1232\text{MeV}$$

From Mainz isobar parametrization (MAID)
Assumption: constant in range W=1232 ± 50 MeV, 0 outside

- Solid angle & detector efficiency

front surface of detector array: 200 cm²
distance from target: r = 20 cm

$$\Delta\Omega \approx \frac{\Delta A}{r^2} = \frac{200\,\text{cm}^2}{400\,\text{cm}^2} = 0.5\,\text{sr} \times \underbrace{0.5 \cdot \frac{1}{4\pi}}_{\text{for 2nd photon}} = 0.02\,\text{sr}$$

Estimation of π^0 count rate

- Target geometry

$$n_p^{\text{target}} = \frac{L}{A}\rho \cdot m = \frac{6\cdot 10^{23}}{14g}\cdot 1\,\text{g/cm}^3 \cdot 1\,\text{cm} \cdot 8$$

$$\approx 3.5\cdot 10^{23}\,\text{cm}^{-2}$$

for 1cm CH_2 target, always 8 protons

- Tagger efficiency $\varepsilon_{tag} \approx 0.8$
- All together

$$N_\pi = 3.7\cdot 10^5\,\text{s}^{-1}\cdot 3.5\cdot 10^{23}\,\text{cm}^{-2}\cdot 28.5\cdot 10^{-30}\,\text{cm}^2/\text{sr}\cdot 0.02\,\text{sr}\cdot 0.8$$

$$= 5.9\cdot 10^{-2}\,\text{s}^{-1}$$

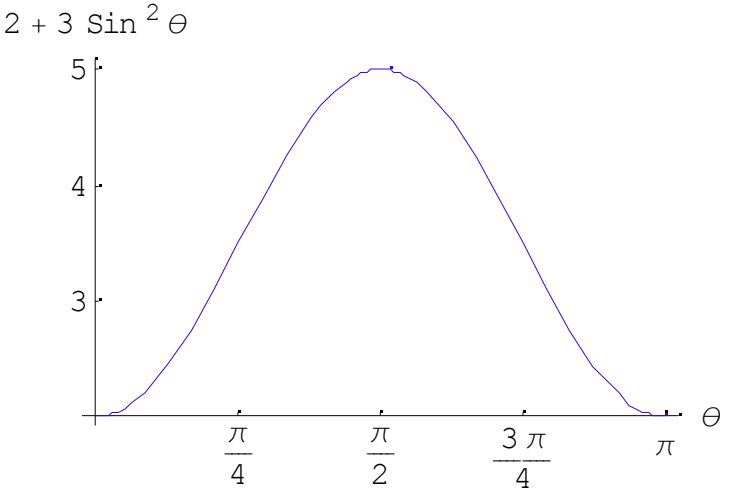
$$\Rightarrow \mathbf{212\,\pi^0\ per\ hour\ detectable}$$

Kinematics

$$\gamma + p \rightarrow \Delta^{+}(1232) \rightarrow p + \underbrace{\pi^{0}}_{2\gamma}$$

- Excitation of p into $\Delta^{+}(1232)$ at E_{γ} = 340 MeV
- Angular distribution depends on total spin

J	P	l_{π}	W(θ)	initial photon
1/2	-	0	1	E1
1/2	+	1	1	M1
3/2	+	1	$2 + 3\sin^2(\theta)$	M1
3/2	-	2	$2 + 3\sin^2(\theta)$	E1
3/2	+	1	$1 + \cos^2(\theta)$	E2
3/2	-	2	$1 + \cos^2(\theta)$	M2



initial photon:
magnetic dipole

$$\left.\frac{d\sigma}{d\Omega}\right|_{\max} @\theta_{CM} = 90^{\circ}$$

Kinematics

- Optimize for $E^{CM} = 1232$ MeV & $\theta_\pi^{CM} = 90°$
- Rest-frame of $\Delta(1232) \rightarrow p + \pi^0$

$$|\vec{p}| = \frac{1}{2M_\Delta} \cdot \sqrt{(M_\Delta^2 - (m_p + m_\pi)^2)(M_\Delta^2 - (m_p - m_\pi)^2)} = 229.3\,\mathrm{MeV/c}$$

- CM-frame moving in lab-frame

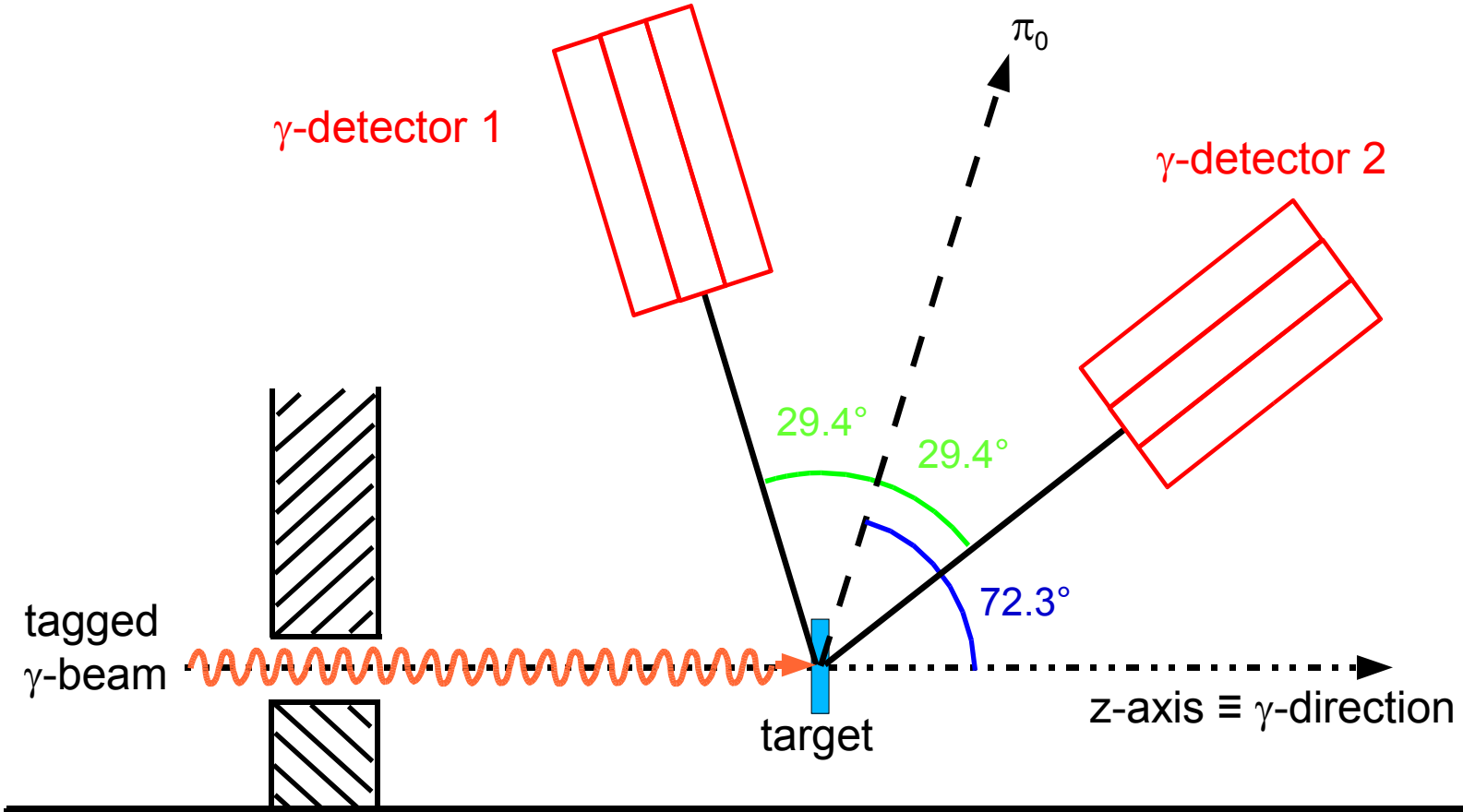
$$p_\pi^{CM} = 229.3\,\mathrm{MeV/c} \equiv p_\pi^\perp$$ Lorentz invariant

$$p_\pi^{II} = \gamma\beta' E' = 72.9\,\mathrm{MeV}$$ Lorentz transformed

$$\tan\theta_{lab} = \frac{229.3}{72.9} \rightarrow \theta_{lab} = 72.3°$$

$$\beta' = \frac{p_\gamma^{lab}}{E_\gamma^{lab} + m_p} = \frac{340}{340 + 938.3} = 0.266$$

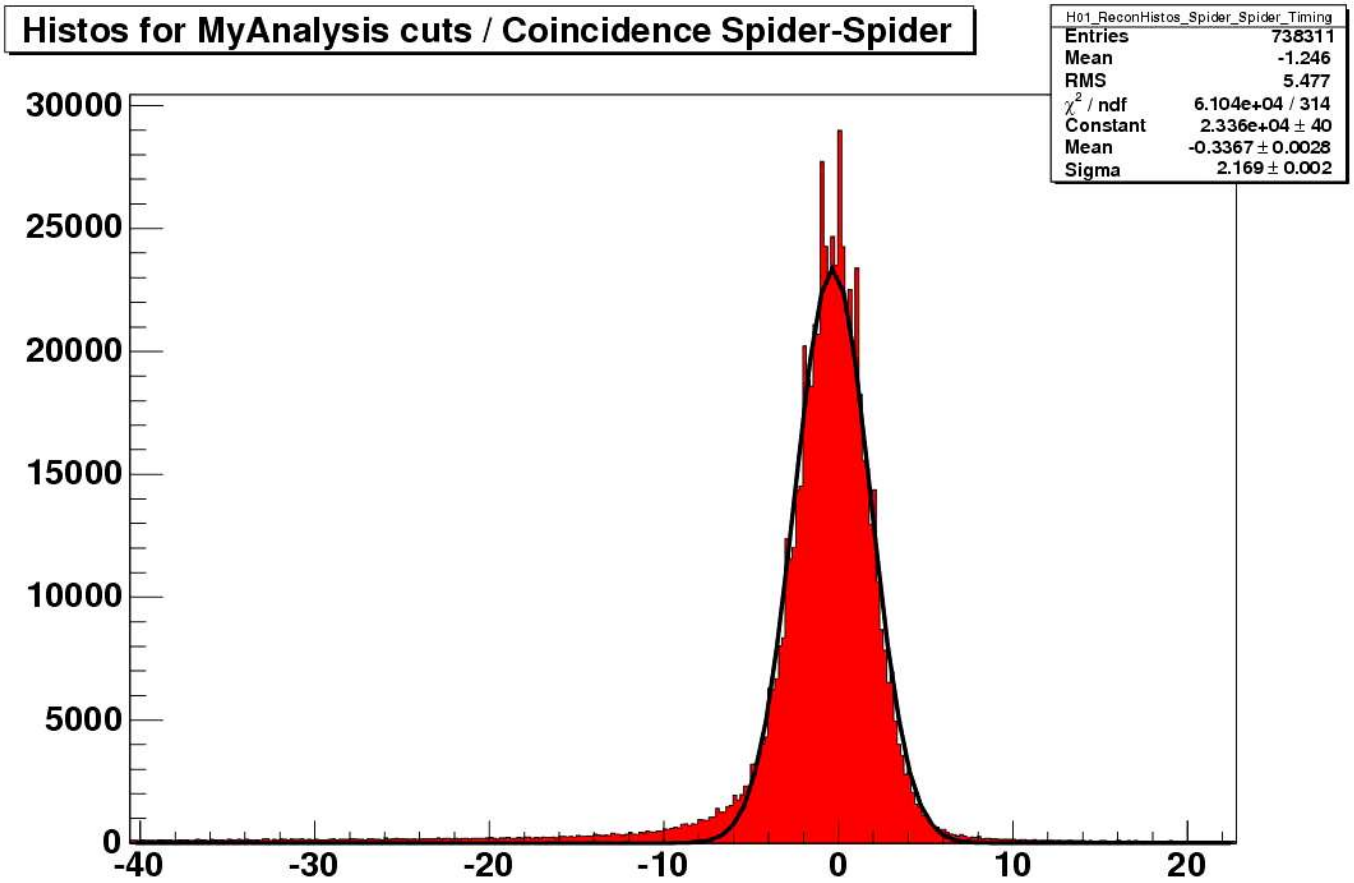
Experimental setup



E^{CM}/MeV	E_γ^{lab}/MeV	θ_π^{lab}	p'_π/MeV	p_π^{lab}/MeV	$\theta_{\gamma\gamma}^{min}$	θ_π^{CM}
1232	340	72.3°	229.3	240.6	58.8°	90°

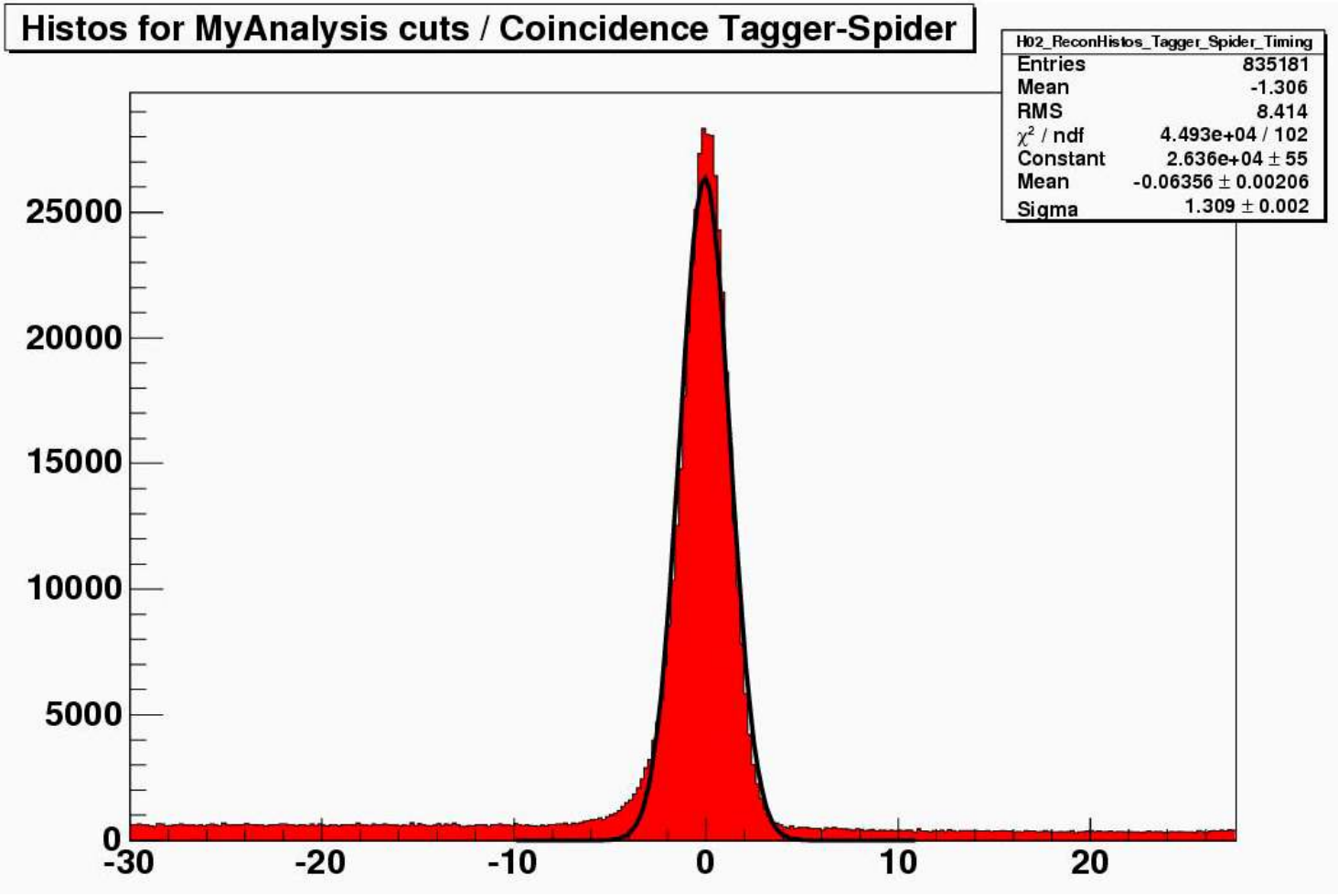
π^0 identification

- 2 time cuts:
  - Coincidence between 2 events, one in each array



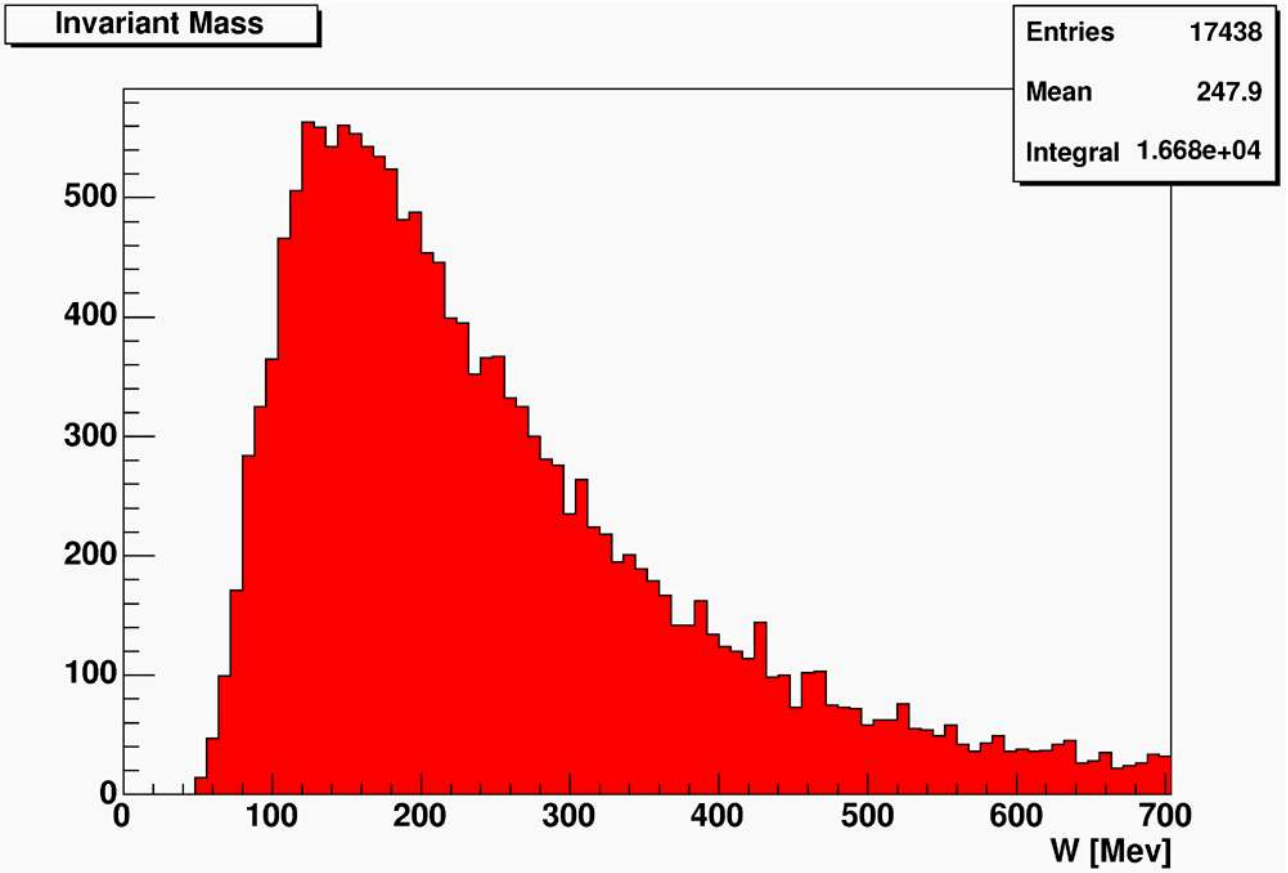
π^0 identification

- Coincidence between tagger and detector events



π^0 identification

- Energy calibration of detectors
  - Invariant mass of pion shifted to PDG value
  - Thus no further cut on invariant pion mass possible



π^0 count rate in experiment

- Calculated count rate:

  212 π^0 per hour could be detected

- Estimate of measured count rate:
  - 14 hours of data acquisition
  - 17438 π^0 identified in data
  - 60% “lifetime” of TDC/ADC

    $\Rightarrow$ 2076 π^0 events per hour

- Many possible background events

Excitation function

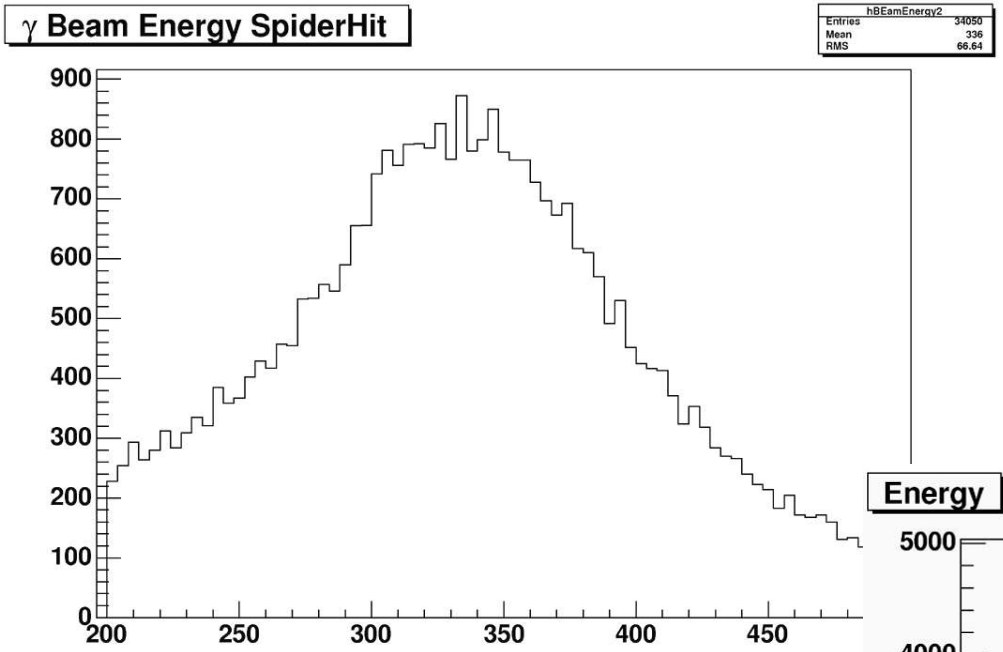
- Energy dependence of differential cross section
  - Differential cross section

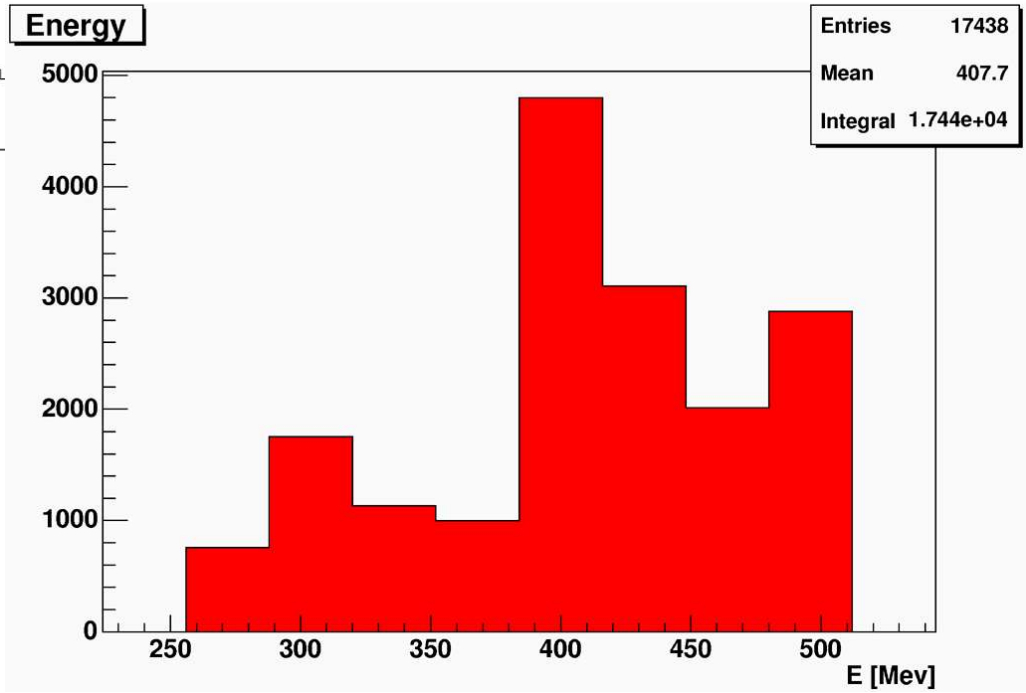
$$\frac{d\sigma}{d\Omega} = \frac{1}{N_{\text{beam}} n_p^{\text{target}} \varepsilon_{\text{det}} \varepsilon_{\text{tag}}} \cdot \frac{N_\pi}{\Delta\Omega}$$

- Convolution of multiple functions in experimental data

$$N_\pi \propto \frac{d\sigma}{d\Omega} * \frac{1}{E_\gamma} * \text{acceptance}$$

Excitation function

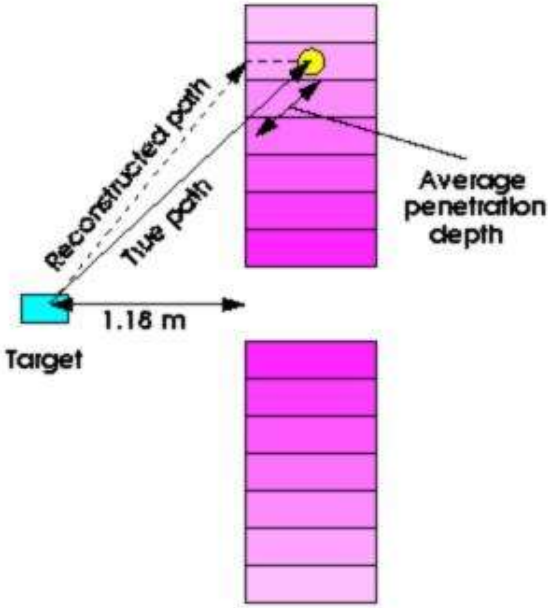




π^0 angular distribution

- Corrected angular distribution in terms of average penetration depth of γ in detector

$$X_{\text{penetration}} = X_0 \cdot \left[\log\left(E / E_{crit}\right) + W_0\right]$$



- Positioning of detectors affects measured angular distribution
- Expected distribution could not be extracted from data

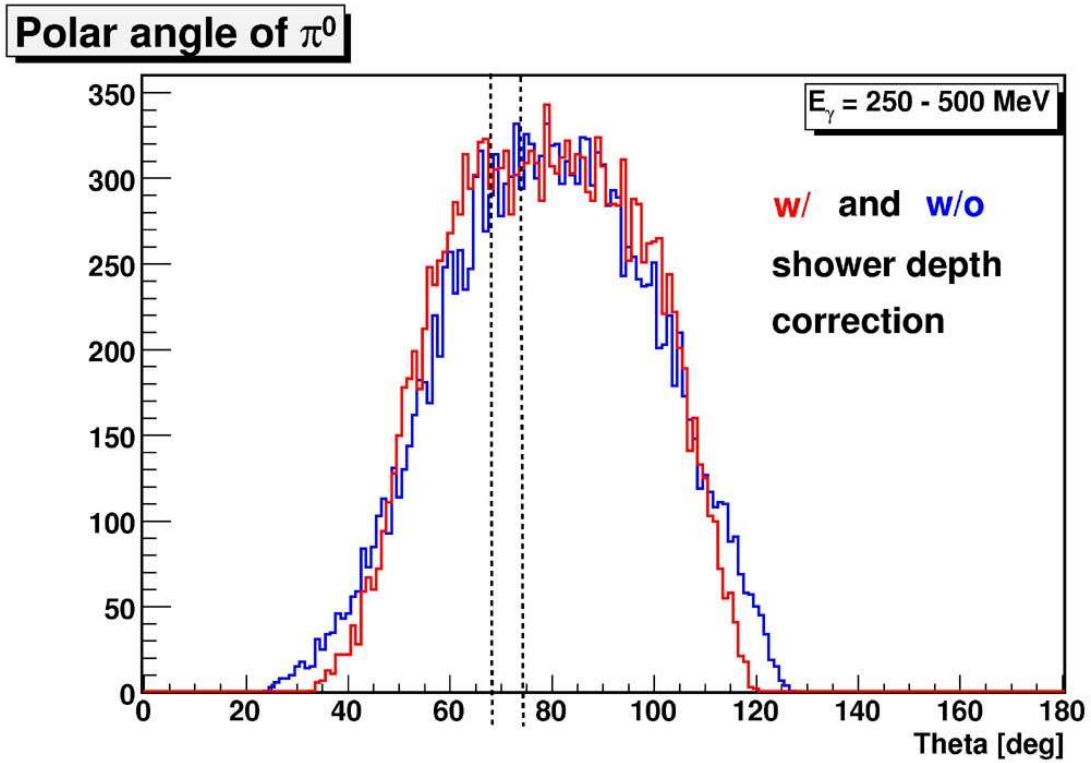
Lead glass (SF5 - Schott)

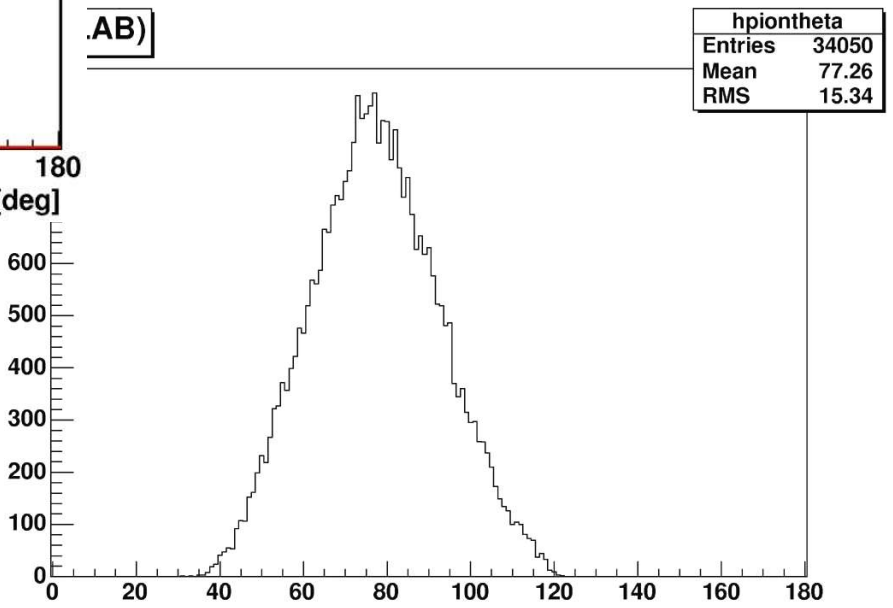
$E_{\text{crit}} = 16.9\ \text{MeV}$

$X_0 = 2.55\ \text{cm}$

$W_0 = 1.2\ (\text{from TAPS})$

π^0 angular distribution





Summary

- Recap of count rate and detector setup due to experiment kinematics
- Description of π^0 identification in data sets
- Estimation of count rate in experiment
- Excitation function as objective of experiment
- Angular distribution of pions
- Comparison between results of acquired data and Monte Carlo simulation