Measurement of the Radiative Widths of $a_2(1320)$ and $\pi_2(1670)$ at COMPASS

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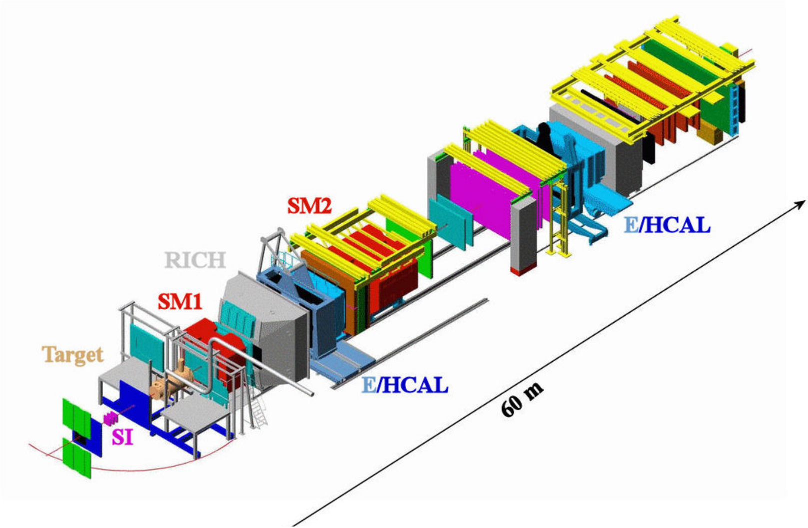
Outline

The COMPASS Experiment

Overview



The COMPASS Experiment

Overview

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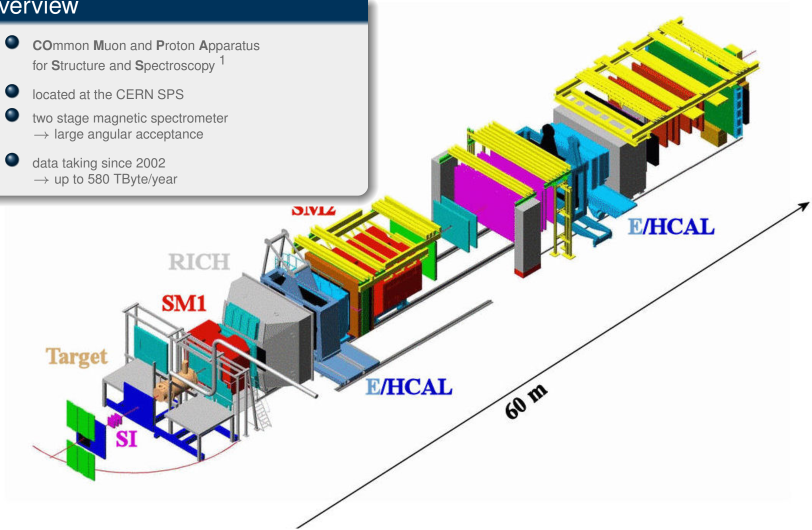
- **CO**mmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy [1]
- located at the CERN SPS
- two stage magnetic spectrometer
  $\longrightarrow$ large angular acceptance
- data taking since 2002
  $\longrightarrow$ up to 580 TByte/year



The COMPASS Experiment

Overview

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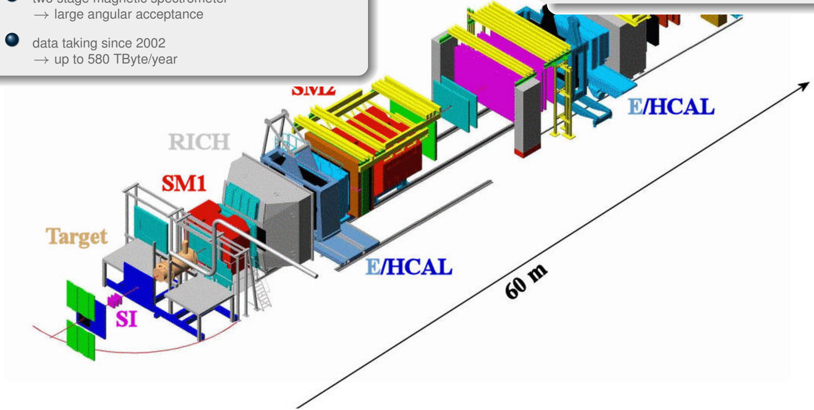
Beam Rates

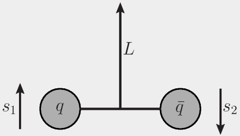
- (tertiary) Muon:
  $\rightarrow 4\cdot10^7 s^{-1}$
- (secondary) Hadron (π, K, ...):
  $\rightarrow 5\cdot10^6 s^{-1}$



Internal Structure

Quark Model

- $q\bar{q}$ system with J^{PC} composed of s_1, s_2 and L
- $X \to \pi\gamma \Leftrightarrow$ Electromagnetic transition
- Sensitive to electric ($\pi_2(1670) \to \pi$) and magnetic ($a_2(1320) \to \pi$) quadrupole momentum



E1	$\Delta J = 1, \Delta P \neq 0$	e.g. $J^{PC} = 1^{++} \to 0^{-+}$
E2	$\Delta J = 2, \Delta P = 0$	e.g. $J^{PC} = 2^{-+} \to 0^{-+}$ ($\pi_2(1670) \to \pi$)
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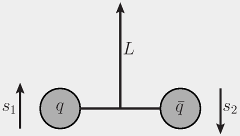

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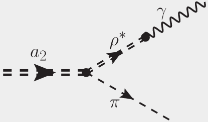
Vector Meson Dominance (VMD) Model

- The photon is a superposition of the pure electromagnetic photon γ and vector mesons ρ, ω and ϕ
- ρ, ω, ϕ and γ have $J^{PC} = 1^{--}$
- $X \rightarrow \rho\pi \leftrightarrow X \rightarrow \pi\gamma$



Present Status of Radiative Widths

Theory

- $\Gamma(a_2(1320) \to \pi\gamma)$

Vector Meson Dominance Model:	375 keV	[Rosner, 1981]
Relativistic Quark Model:	324 keV	[Aznauryan and Ogamesyan, 1988]
Covariant Oscillator Quark Model:	235 keV	[Ishida et al., 1989]

- $\Gamma(\pi_2(1670) \to \pi\gamma)$

Covariant oscillator quark model:	335 keV / 521 keV	[Maeda et al., 2013]

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Measurements

- $\Gamma(a_2(1320) \to \pi\gamma)$

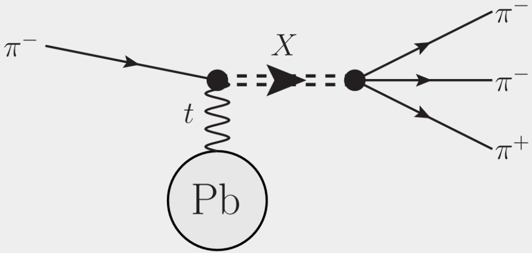
May et al.	$\Gamma(a_2(1320)^\pm \to \pi^\pm\gamma) = 0.46 \pm 0.11\,\text{MeV}$	[May et al., 1977]
E272	$\Gamma(a_2(1320)^- \to \pi^-\gamma) = 295 \pm 60\,\text{keV}$	[Cihangir et al., 1982]
SELEX	$\Gamma(a_2(1320)^- \to \pi^-\gamma) = 284 \pm 25 \pm 25\,\text{keV}$	[Molchanov et al., 2001]

- $\Gamma(\pi_2(1670) \to \pi\gamma)$
  No published results

Primakoff Reaction

Primakoff Reaction

- $\pi\gamma$ decays are difficult to access experimentally
- Primakoff: Coulomb potential $\Rightarrow$ quasi real photon
- Use $\pi\gamma$ interactions in Primakoff production



Primakoff Production at COMPASS

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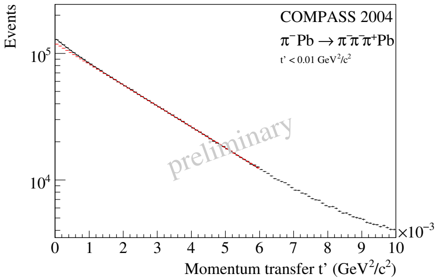
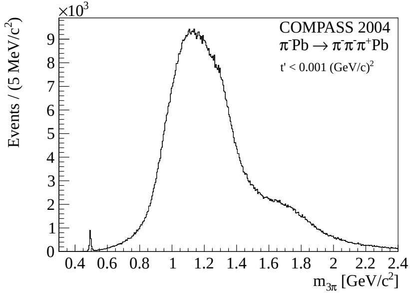
COMPASS 2004 Run with Hadrons

- 190 GeV π^- beam on Pb target
- Small admixture of K^- and $\bar{p}$
- Trigger: Multiplicity
- $\approx 4 \cdot 10^6$ exclusive $\pi^-\pi^-\pi^+$ events recorded
- $\approx 1 \cdot 10^6$ for $t' < 10^{-3}\,\mathrm{GeV}^2/c^2$

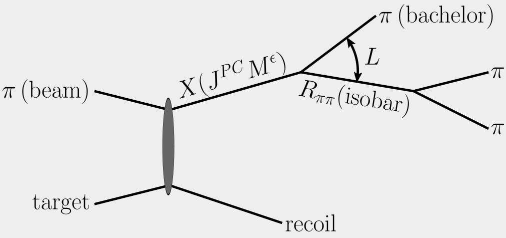




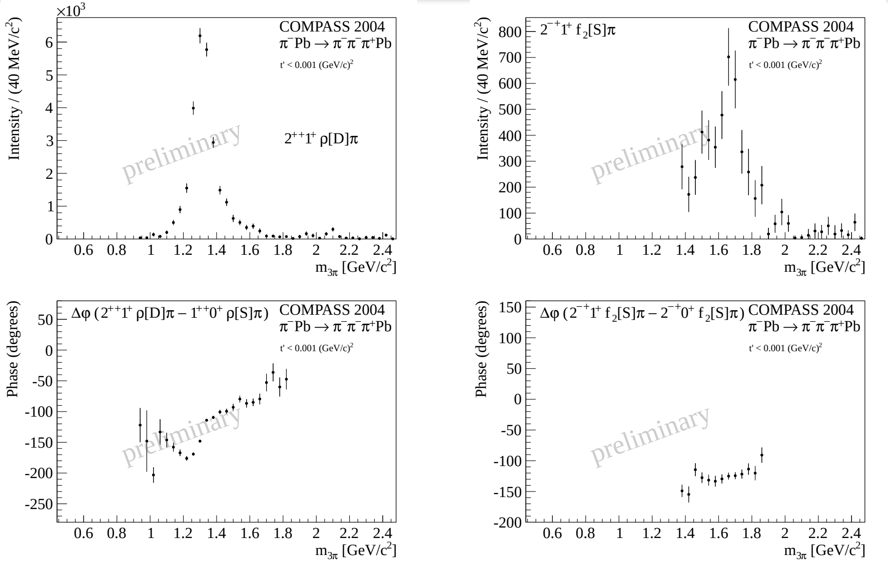
Characteristics of PWA

PWA

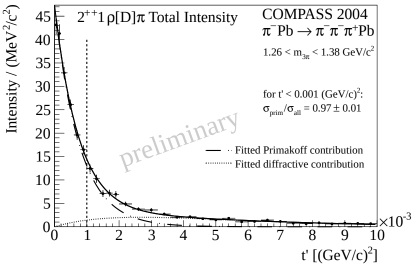
- Isobar model: Intermediate 2-particle decays
- Partial waves in reflectivity basis: $J^{PC} M^{\epsilon} \{isobar\} [L] \pi$
- PWA in 40 MeV/c^2 mass bins
- PWA fit to full phase-space
- For very low t': $M = 0$: Diff. Prod, $M = 1$: Primakoff Prod.

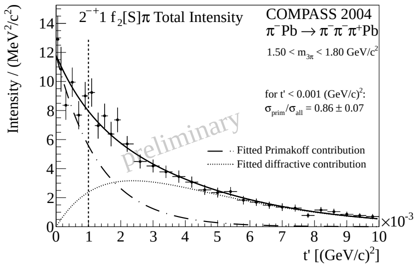


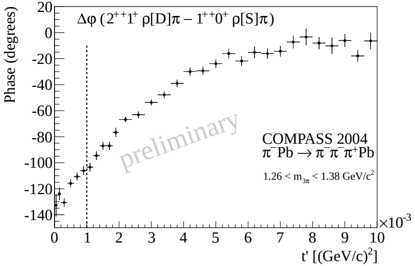
PWA in mass bins ($t' < 0.001\ \mathrm{GeV}^2/c^2$)

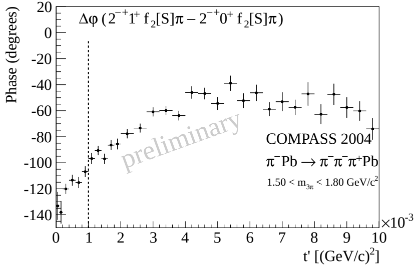


PWA in t' bins (around m_0)









Radiative width and the total cross-section

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Primakoff production of a broad resonance X from Pion beam

$$\frac{\mathrm{d}\sigma}{\mathrm{d}m\mathrm{d}t'} = 16\alpha Z^2 \left(\frac{m}{m^2 - m_\pi^2}\right)^3 \frac{m_0^2 \Gamma_{\pi\gamma}(m) \Gamma_{final}(m)}{\left(m^2 - m_0^2\right)^2 + m_0^2 \Gamma_{total}(m)^2} \frac{t'}{(t' + t_{min})^2} \left|F(t')\right|^2 \quad (1)$$

with

$$\Gamma_{\pi\gamma}(m) = f_{\pi\gamma}^{dyn}(m) \cdot \Gamma_0(X \to \pi\gamma)$$

Radiative width and the total cross-section

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Primakoff production of a broad resonance X from Pion beam

$$\frac{d\sigma}{dm\,dt'} = 16\alpha Z^2 \left(\frac{m}{m^2 - m_\pi^2}\right)^3 \frac{m_0^2 \Gamma_{\pi\gamma}(m) \Gamma_{final}(m)}{\left(m^2 - m_0^2\right)^2 + m_0^2 \Gamma_{total}(m)^2} \frac{t'}{(t' + t_{min})^2} \left|F(t')\right|^2 \qquad (1)$$

with

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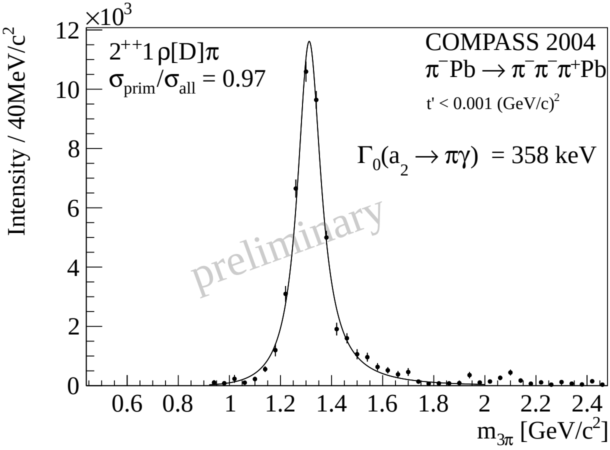
Radiative width and the total cross-section

$$\sigma_{Primakoff} = \int_{m_1}^{m_2} \int_{t'_1=0}^{t'_2} \frac{d\sigma}{dm\,dt'} dt' dm = \Gamma_0(X \to \pi\gamma) \cdot C_X = \frac{N_X/\epsilon}{\mathcal{L} \cdot CG^2 \cdot BR \cdot \epsilon_{resol}} \qquad (2)$$

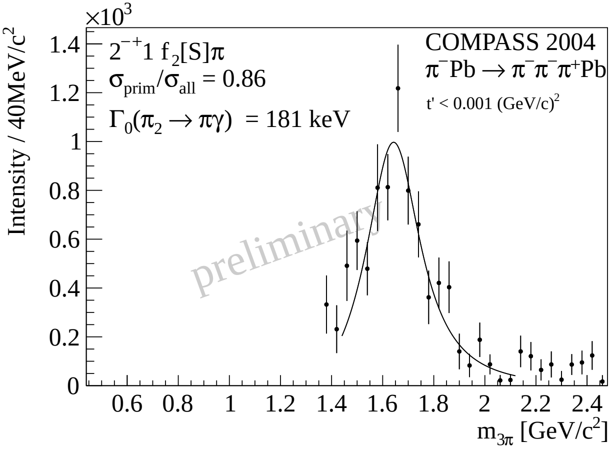
- N_X/ϵ: Breit-Wigner fit to the acceptance-corrected PWA intensity
- C_X calculated for specific resonance X
- Luminosity $\mathcal{L}$ determined using decays of beam Kaons $K^-_{beam} \to \pi^-\pi^-\pi^+$
- ϵ_{resol} accounting for experimental resolution

$a_2(1320)$



$\Gamma_0\,(a_2\,(1320) \to \pi\gamma) = 358 \pm 6 \pm 42\,\mathrm{keV}$

$\pi_2(1670)$



$$\Gamma_0\left(\pi_2\left(1670\right) \to \pi\gamma\right) = \left(181 \pm 11 \pm 27\,\text{keV}\right) \cdot 0.56/BR_{f_2\pi}$$

Conclusion

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Measurement of radiative widths of $a_2(1320)$ and $\pi_2(1670)$ at COMPASS

- Reliable extraction of intensities by PWA
- $a_2(1320)$ (M2 transition) compatible best with VMD predictions

$$\Gamma_0\left(a_2\left(1320\right) \to \pi\gamma\right) = 358 \pm 6 \pm 42\,\text{keV}$$

- First measurement of $\pi_2(1670)$ (E2 transition)

$$\Gamma_0\left(\pi_2\left(1670\right) \to \pi\gamma\right) = \left(181 \pm 11 \pm 27\,\text{keV}\right) \cdot 0.56/BR_{f_2\pi}$$

- Paper in preparation
- Analysis of $\pi^-\mathrm{Ni} \to \pi^-\pi^0\pi^0\mathrm{Ni}$ measurement in 2009 started

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