Hadron physics in the COMPASS experiment: status and proposal on organizational matter

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DLNP

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Project authors

Proposal of the new project

Hadron physics at the COMPASS experiment

within the theme 02-0-1085-2017/2019

Project leader: Guskov A. V.

Laboratory of Nuclear Problems:

Abazov V. M., Alexeev G. D., Anfimov N. V., Denisenko I. I., Frolov V. N., Gridin A. O., Guskov A. V., Jouravlev N. I., Krumshtein Z. V., Maltsev A. I., Mitrofanov E. O., Olshevski A. G., Orlov I. A., Piskun A. A., Rezinko T. V., Rymbekova A., Tokmenin V. V.

Laboratory of Theoretical Physics:

Arbuzov A. B.

mean age - 41 year

Our project “Hadron physics at COMPASS”

SPIN-RELATED PHYSICS

The “COMPASS-II” project

PHYSICS WITH HADRON BEAM

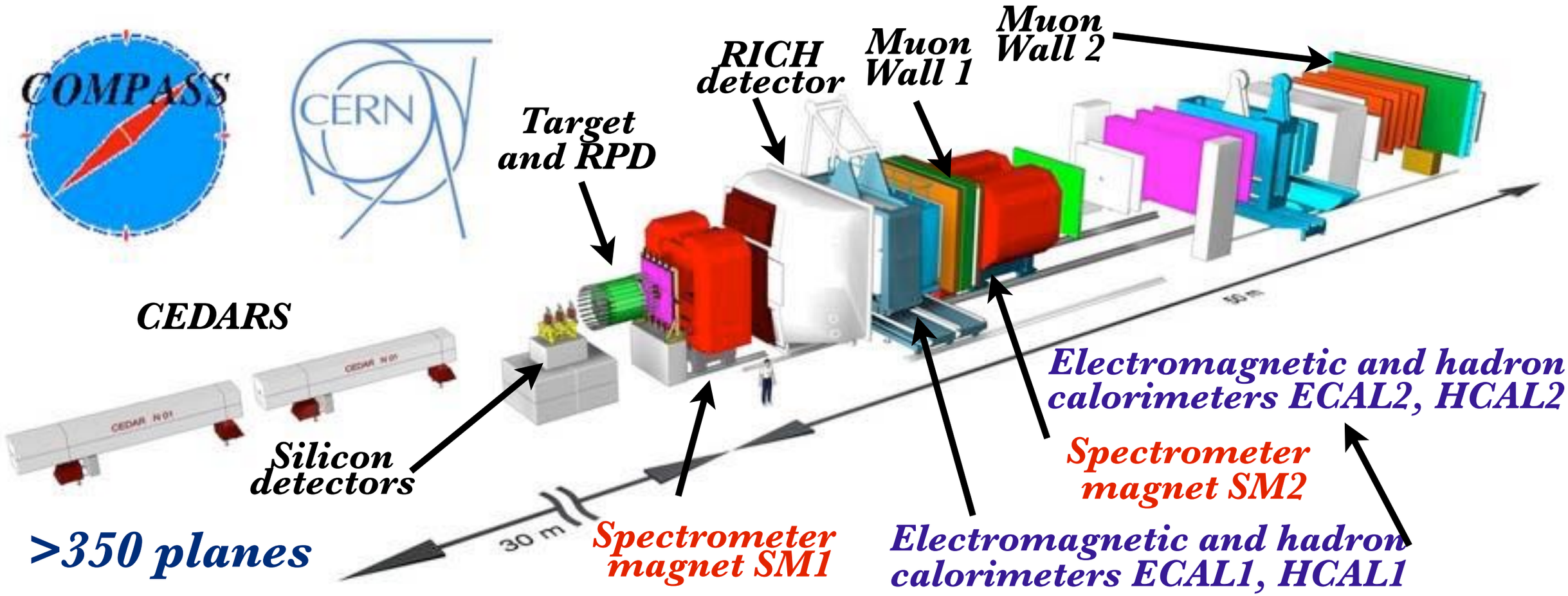
PHYSICS WITH MUON BEAM

SPIN UNRELATED PHYSICS (Primakoff, spectroscopy etc.)

Key points of the project

- **Low energy QCD & Primakoff reactions**
- **EMC effect in pion-induced Drell-Yan**
- **Exotic charmonia**
- **Participation in preparation of the Physics program for COMPASS III**
- **R&D and preparation for the COMPASS setup upgrade for COMPASS III**

The COMPASS setup



Muon beam: $\mu^{+/-}$, P=160-200 GeV/c

Hadron beam: $h^{+/-}$, P=190 GeV/c

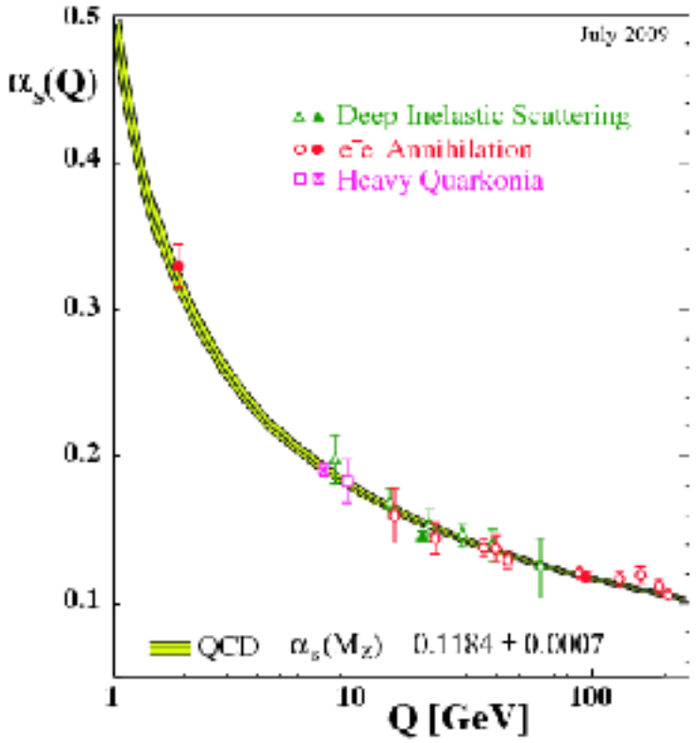
Particles	Positive beam	Negative beam
π	0.240	0.968
K	0.014	0.024
p	0.746	0.008

Composition of the COMPASS hadron beam

Low energy QCD and Primakoff reactions

Leading contribution of JINR group

Low energy QCD



Since the constant of strong interactions $a_S \sim 1$ at small energies, exact QCD formalism cannot make predictions with reasonable accuracy. Effective phenomenological models are needed

Chiral Perturbation theory is one of the most successful phenomenological models at low energies

Mass of light quarks (m,d,s) is much smaller than the typical scale $M \approx 1$ GeV

$$\mathcal{L}_{QCD} = \mathcal{L}^0 + \mathcal{L}_m$$

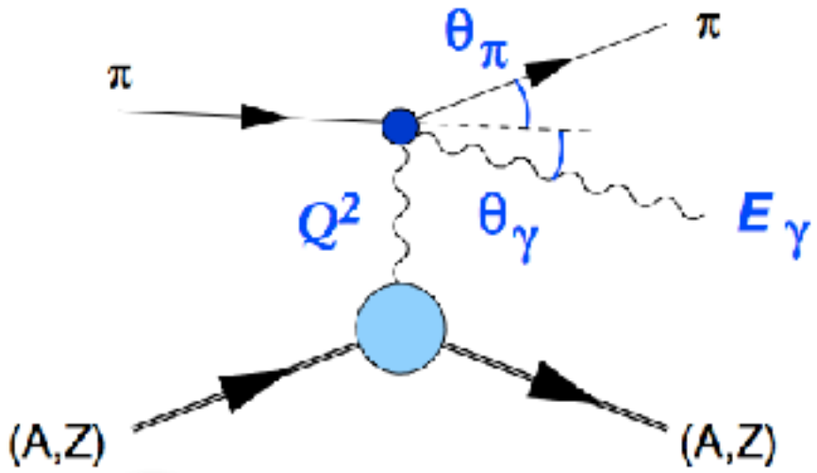
Chiral symmetric term

mass term - a small perturbation

m_q/M , p/M - small parameters in expansion

Study of $\pi\gamma^*$ interaction is a good way to test χPT predictions

Pion and kaon polarizabilities



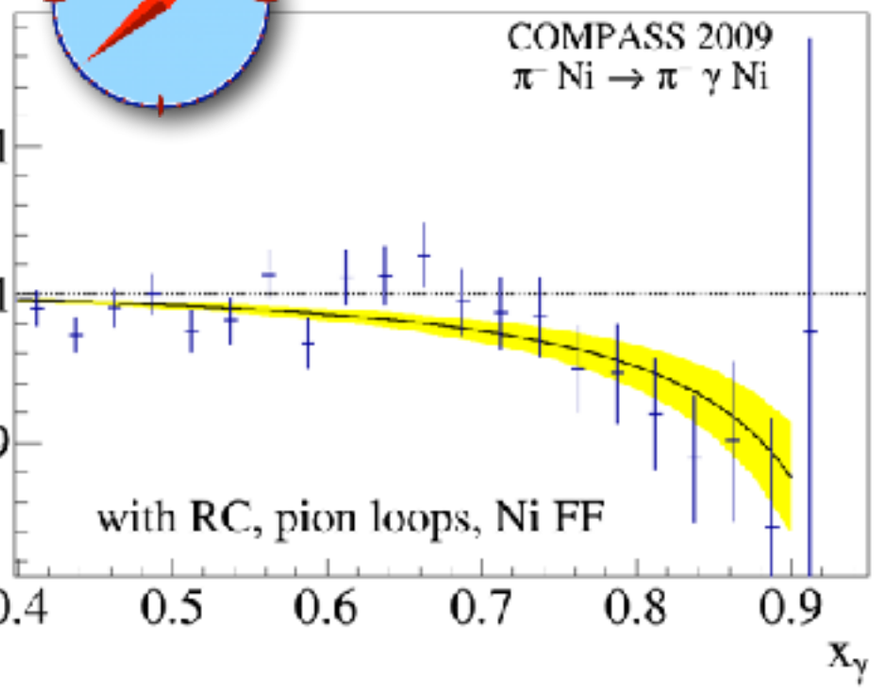
π ELECTRIC POLARIZABILITY α_π — PDG 2016

See HOLSTEIN 14 for a general review on hadron polarizability.

VALUE (10^{-4} fm^3)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.0±0.6±0.7	63k	[1] ADOLPH	15A	SPEC	$\pi^-\gamma \to \pi^-\gamma$ Compton scatt.

[1] Value is derived assuming $\alpha_\pi = -\beta_\pi$.

COMPASS **2009 DONE**



Assumption $\alpha_\pi+\beta_\pi=0$

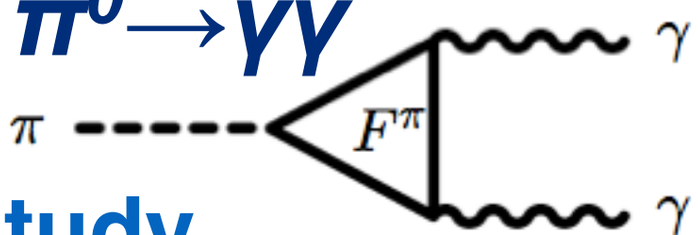
COMPASS **2012 UNDER ANALYSIS**

- ***Reduction of uncertainty of α_π measurement by factor of 3***
- ***Precise independent measurement of α_π and β_π***
- ***First result for kaon polarizabilities***

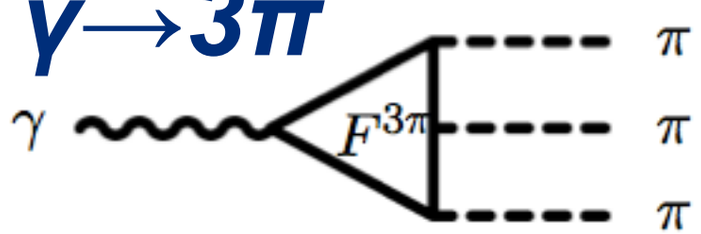
πγ cross sections for other inclusive reactions

$\pi^-\gamma \to \pi^- \pi^0$

$\pi^0 \to \gamma\gamma$



$\gamma \to 3\pi$



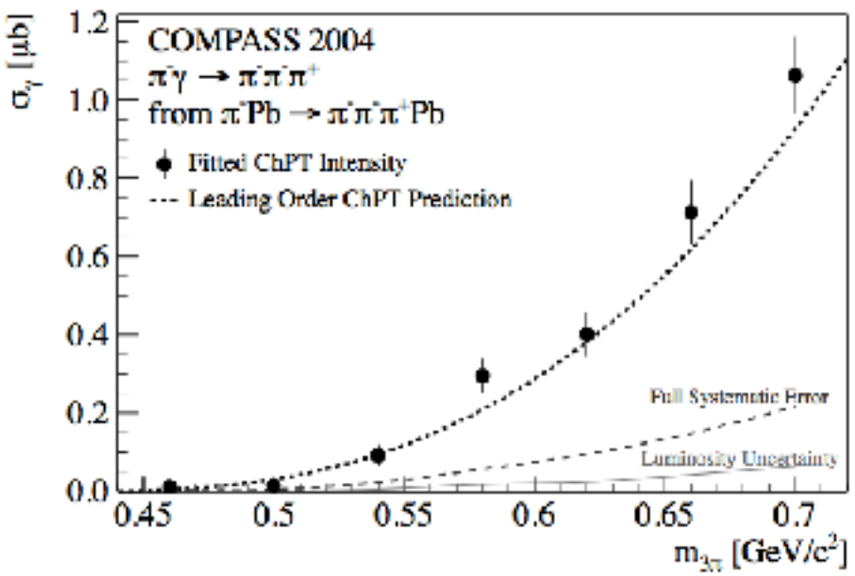
chiral anomaly study

$$F_{3\pi} = \frac{eN_c}{12\pi^2 F_\pi^3} = (9.78 \pm 0.05)\,\mathrm{GeV}^{-3}$$

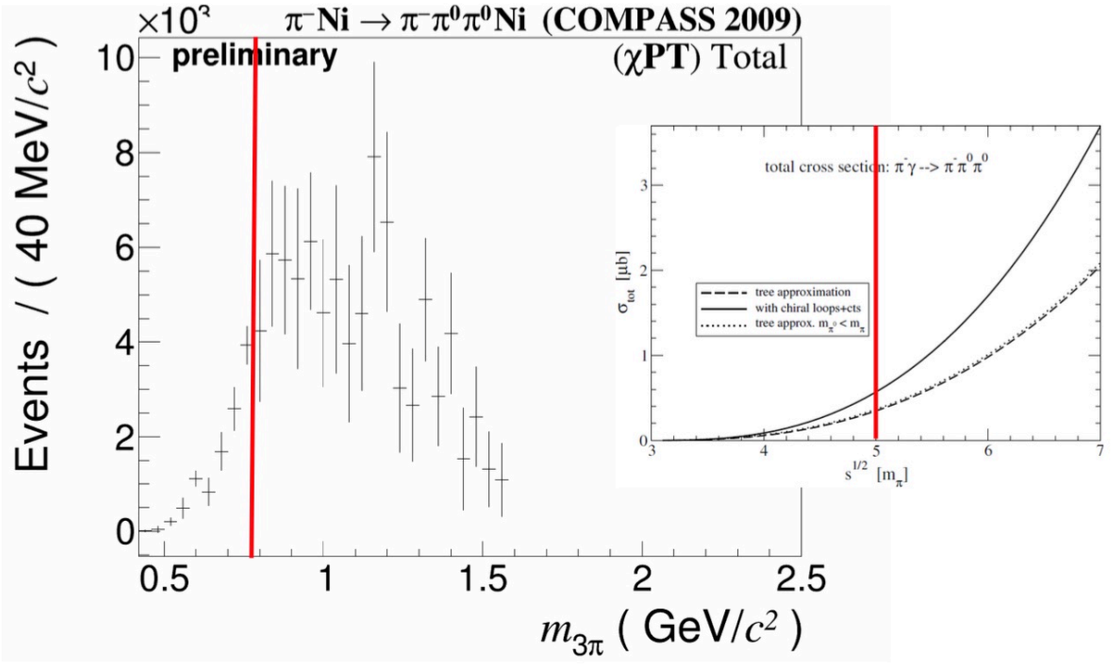
also for $\pi^-\gamma \to \pi^-\eta$

Serpukhov result (1987): 10.7±1.2

$\pi^-\gamma \to \pi^- \pi^+ \pi^-$ (done)



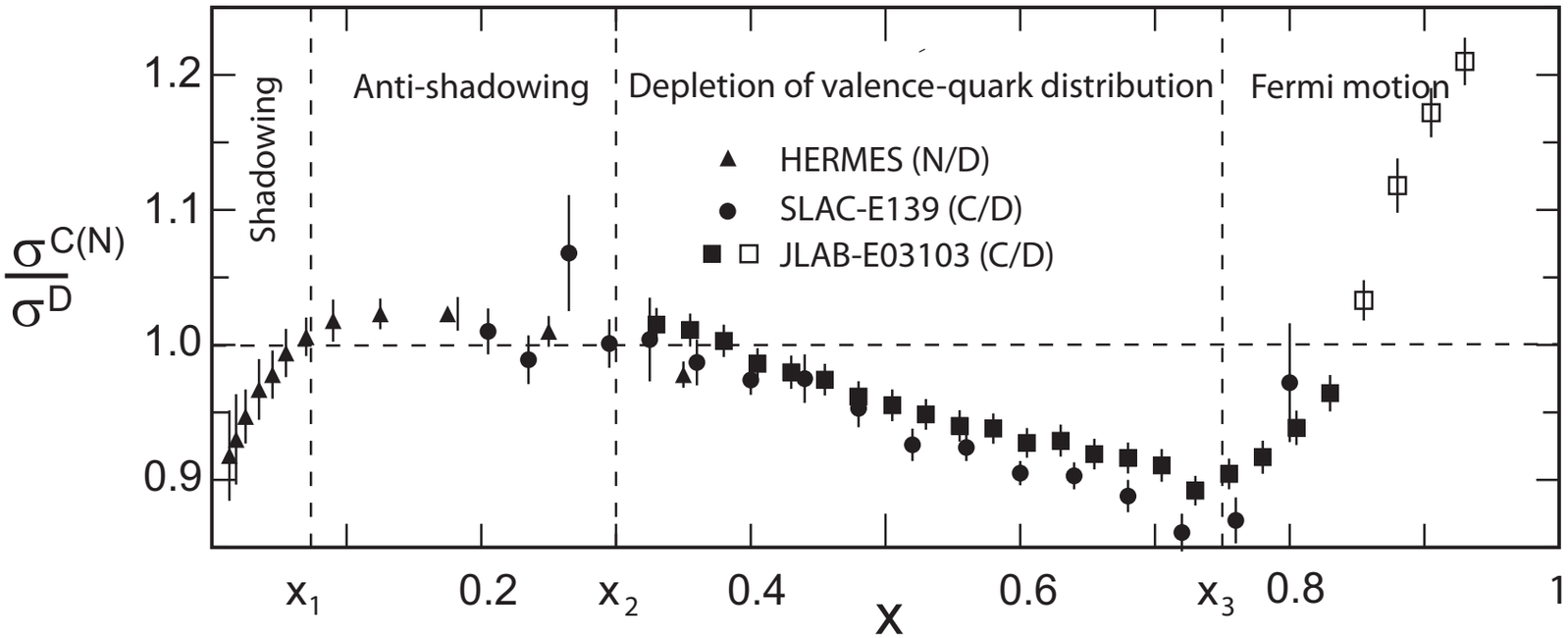
$\pi^-\gamma \to \pi^- \pi^0 \pi^0$ (under analysis)



also for kaon induced reactions

EMC-effect in pion-induced Drell-Yan process

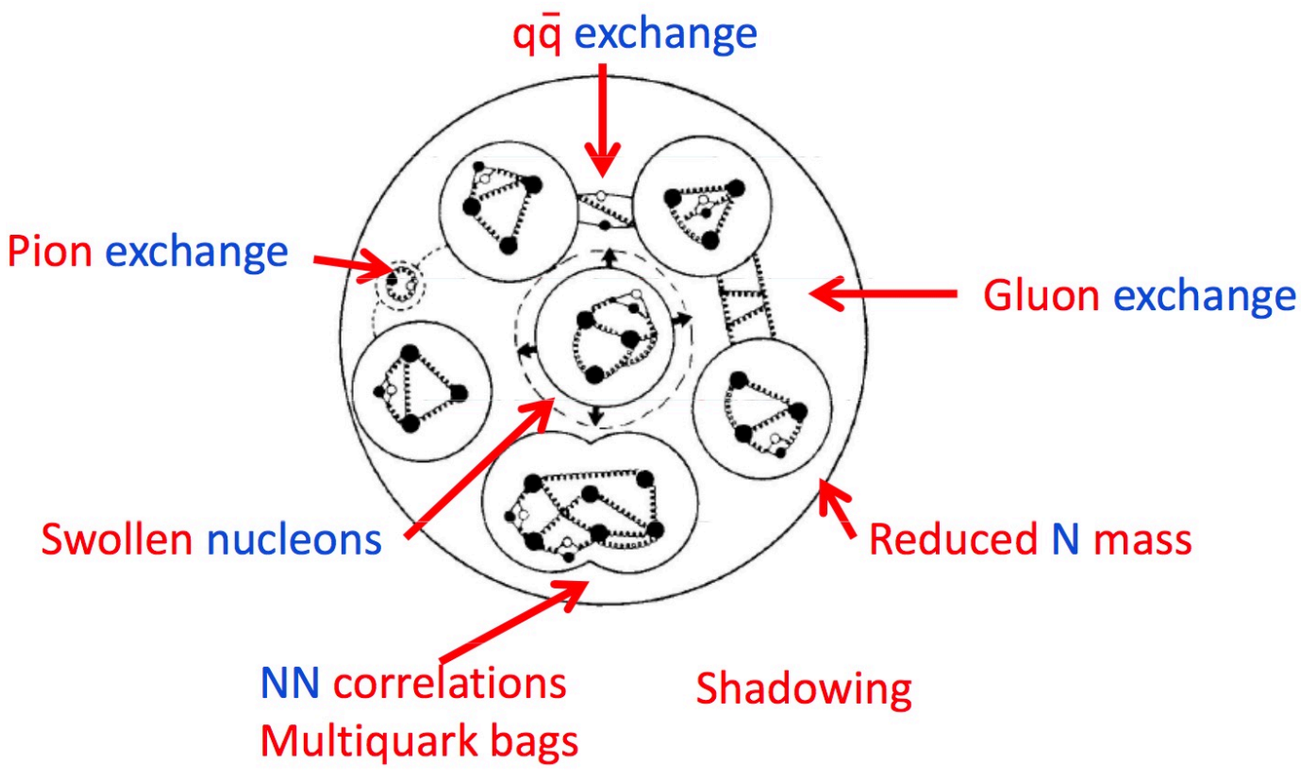
EMC-effect



Nucleon structure depends on the nucleus!

x - fraction of longitudinal momentum of hadron:

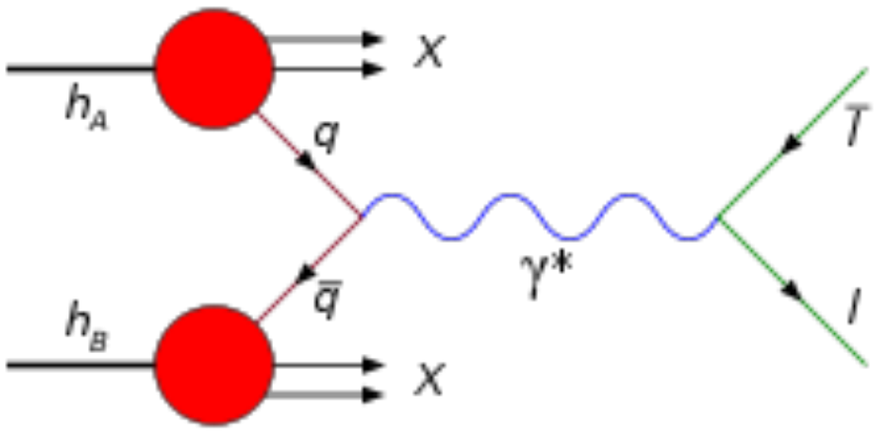
$P_{parton} = x\, P_{hadron}$



Discovered and mainly studied in DIS

A lot of models but no universal model

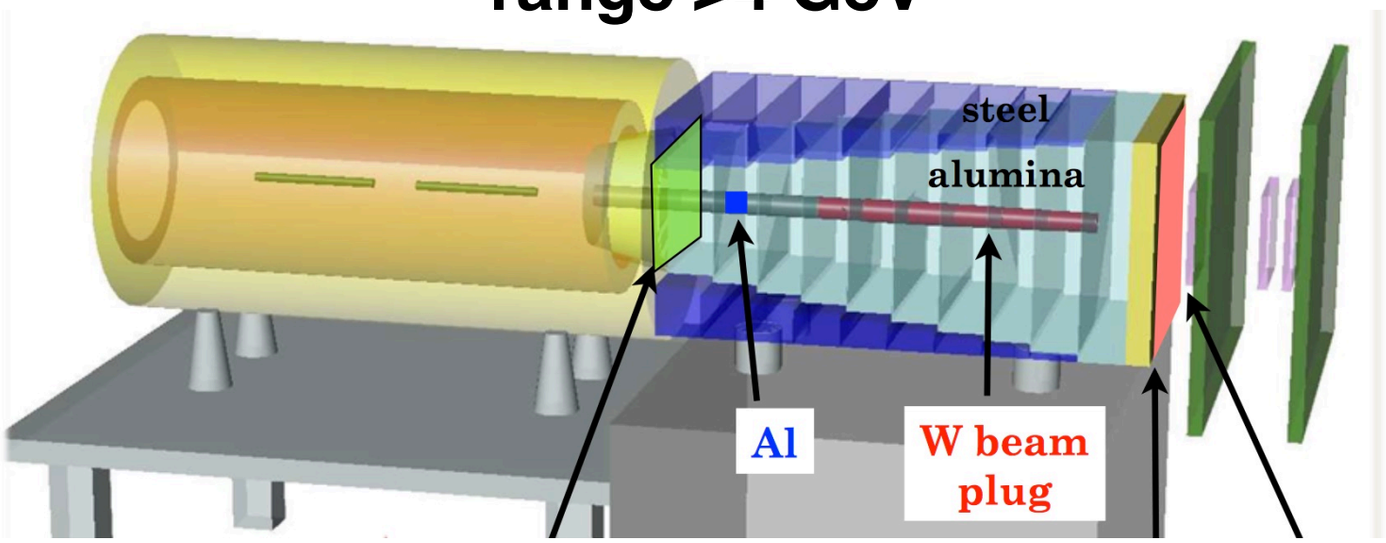
EMC-effect in pion-induced Drell-Yan

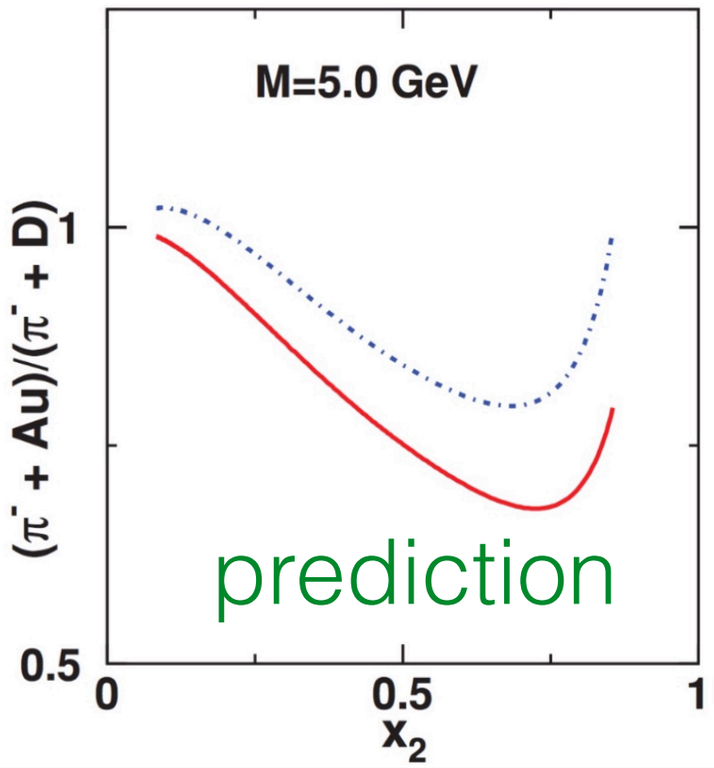


DIS: u and d quarks contribute together

Pion-induced Drell-Yan - only u (π^-) or d (π^+) quarks (in first approximation)

2014, 2015, (2018) data with π^- beam of 190 GeV/c - > 10^5 DY events in the mass range >4 GeV



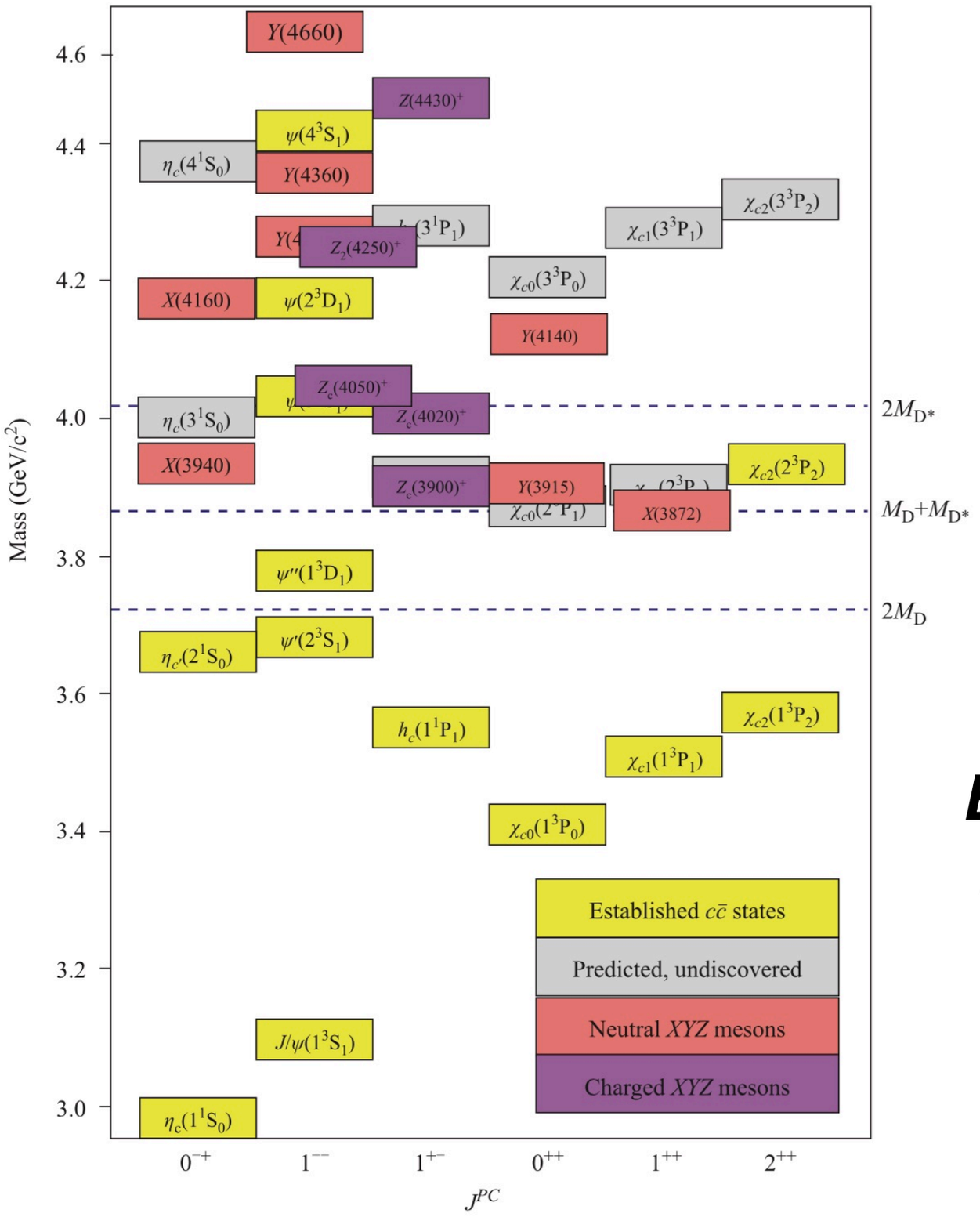


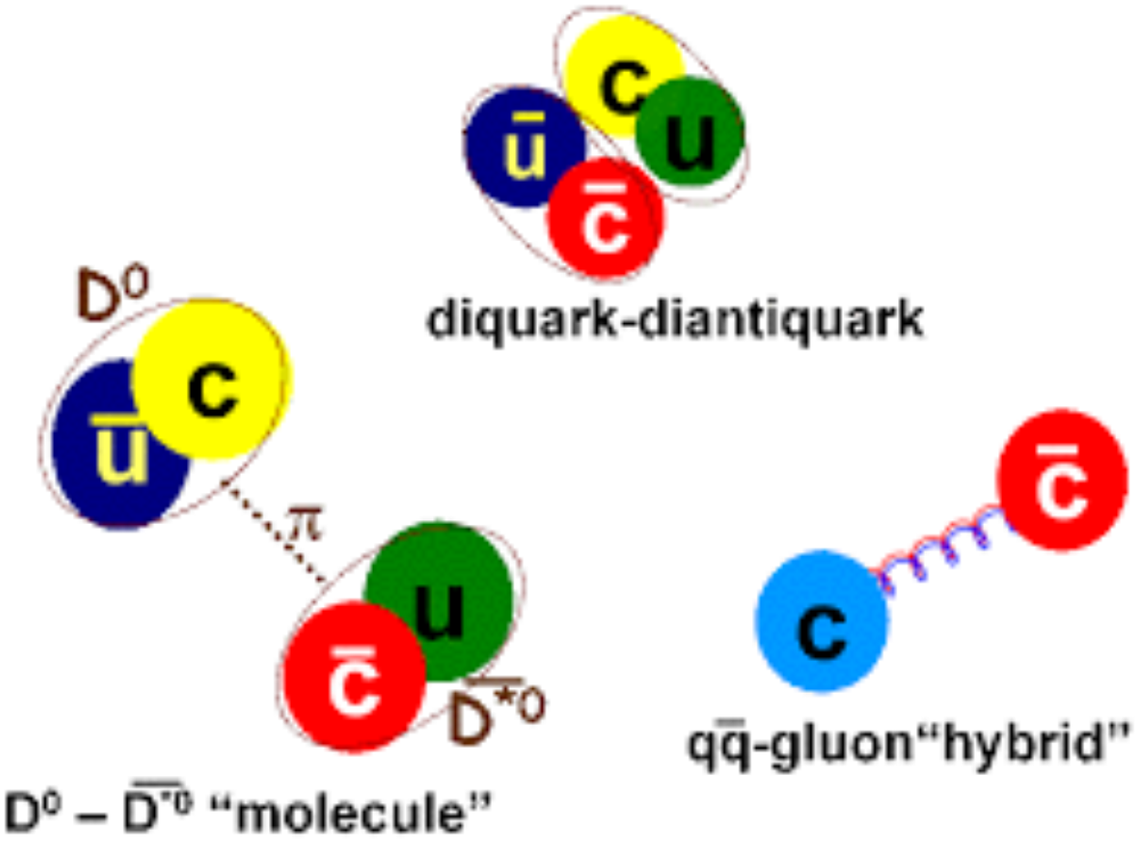
See poster for more details

Lepto-(photo) production of exotic charmonia

JINR group proposal

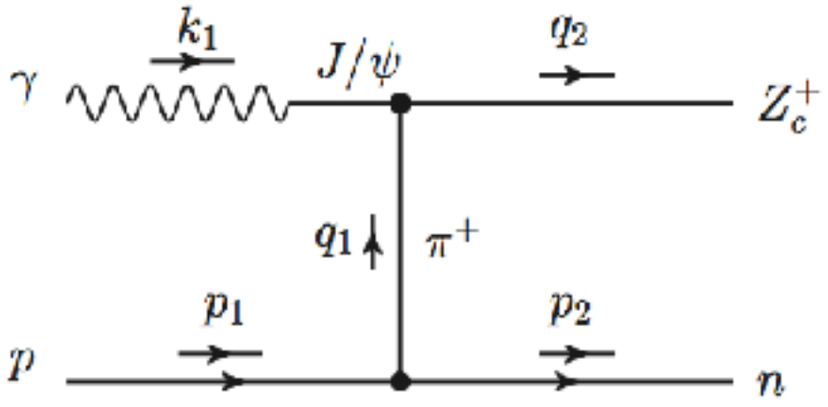
Exotic charmonia



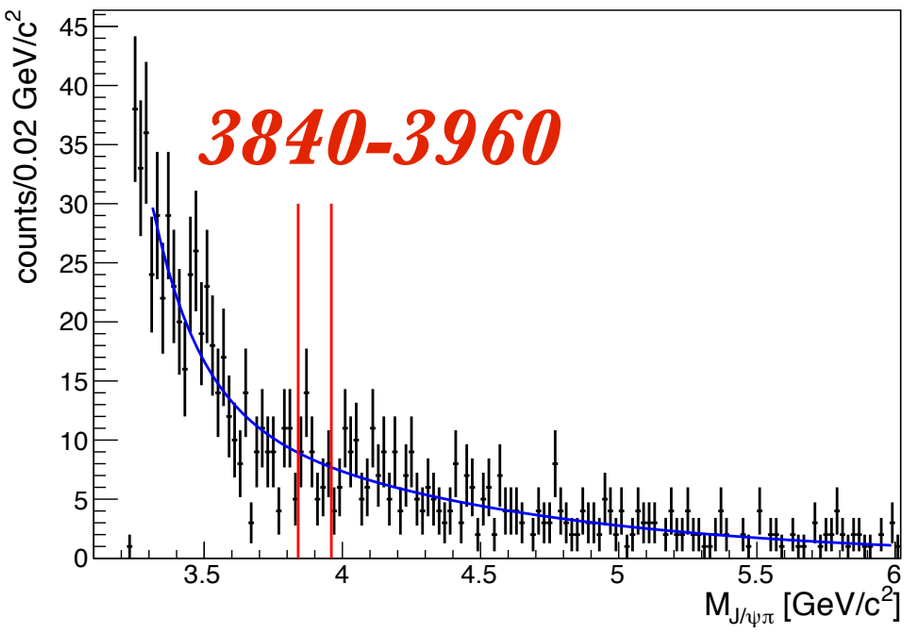


Exotic XYZ states were observed in e^+e^- collisions, decays of the higher states or inclusively in hadronic collisions. Lepto-(photo)production is a new option

$Z_c^{\pm}(3900)$ and X(3872)



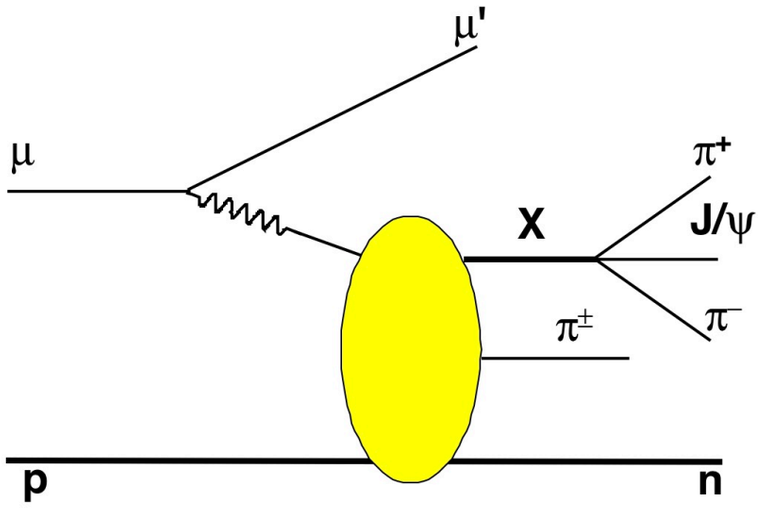
$Z_c(3900)$

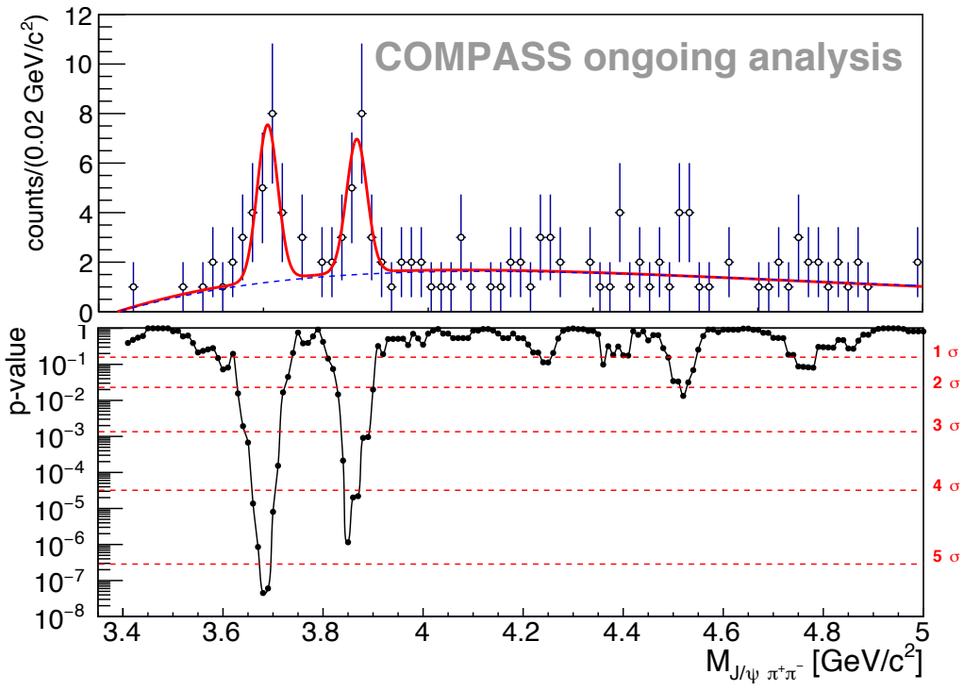


PLB 742 (2015) 330 **PDG 2016**

$$BR(Z_c^{\pm}(3900) \to J/\psi\pi^{\pm}) \times \sigma_{\gamma N \to Z_c^{\pm}(3900) N}\Big|_{(\sqrt{s_{\gamma N}})=13.8\ \mathrm{GeV}} < 52\ \mathrm{pb}.$$

X(3872)





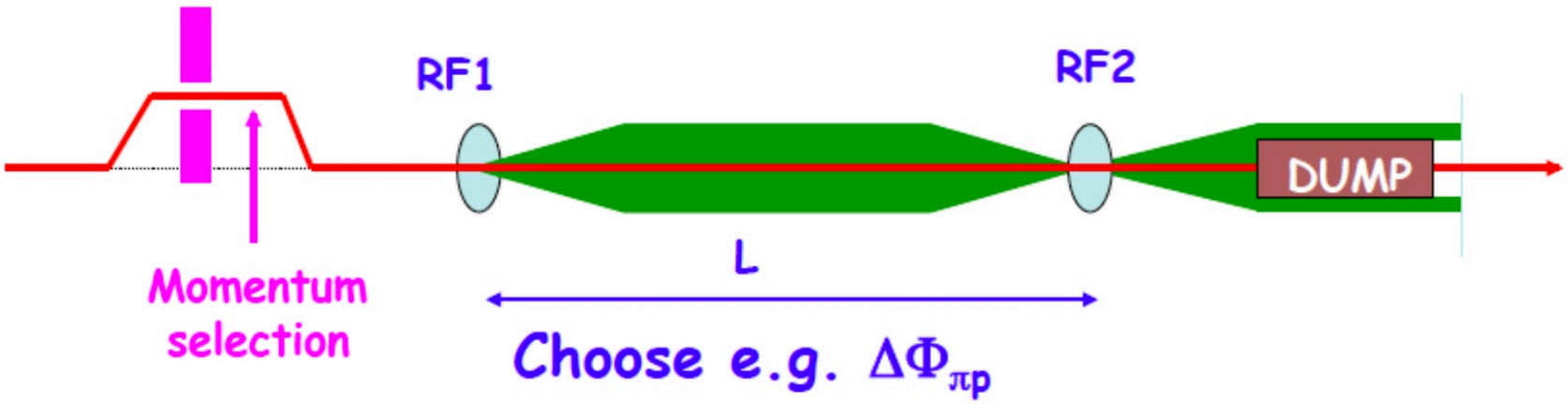
More final states with J/ψ for tests

See poster for more details

COMPASS future with hadron beams

2020+

RF-separated hadron beam



up to 3.2×10^7 s^{-1} for antiprotons and up to 8×10^6 s^{-1} for negative kaons

Low energy QCD with kaon beam:

$K^-(A,Z) \to K^-(A,Z)\,\gamma$

$K^-(A,Z) \to K^-(A,Z)\,\pi^0$

$K^-(A,Z) \to K^-(A,Z)\,\pi^0\,\pi^0$

$K^-(A,Z) \to K^-(A,Z)\,\pi^+\,\pi^-$

$K^-(A,Z) \to K^-(A,Z)\,\eta$

$K^-(A,Z) \to K^{*-}(892)\,(A,Z)$

$K^-(A,Z) \to K^{*-}(1430)\,(A,Z)$

…

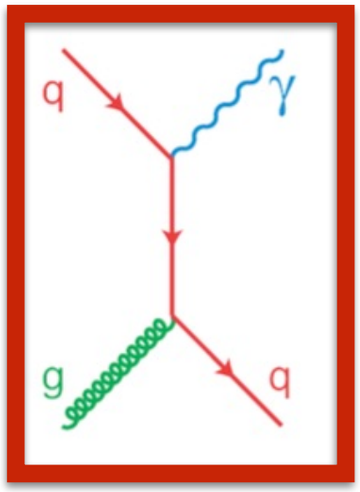
kaon polarizabilities

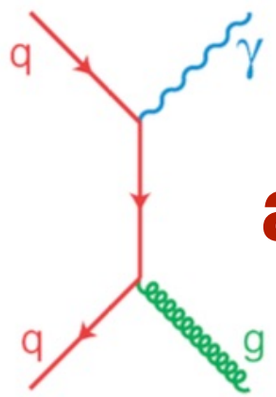
cross sections for χPT test

radiative widths

Prompt photons

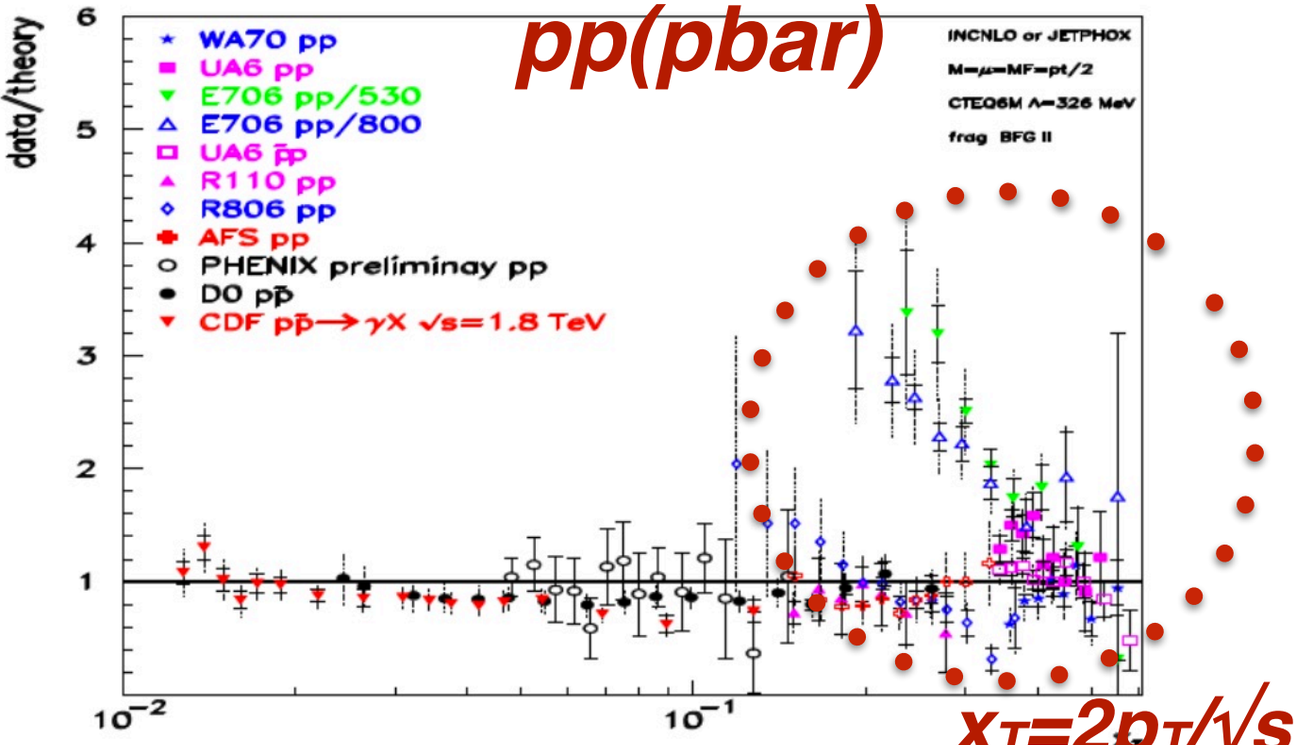
JINR group proposal





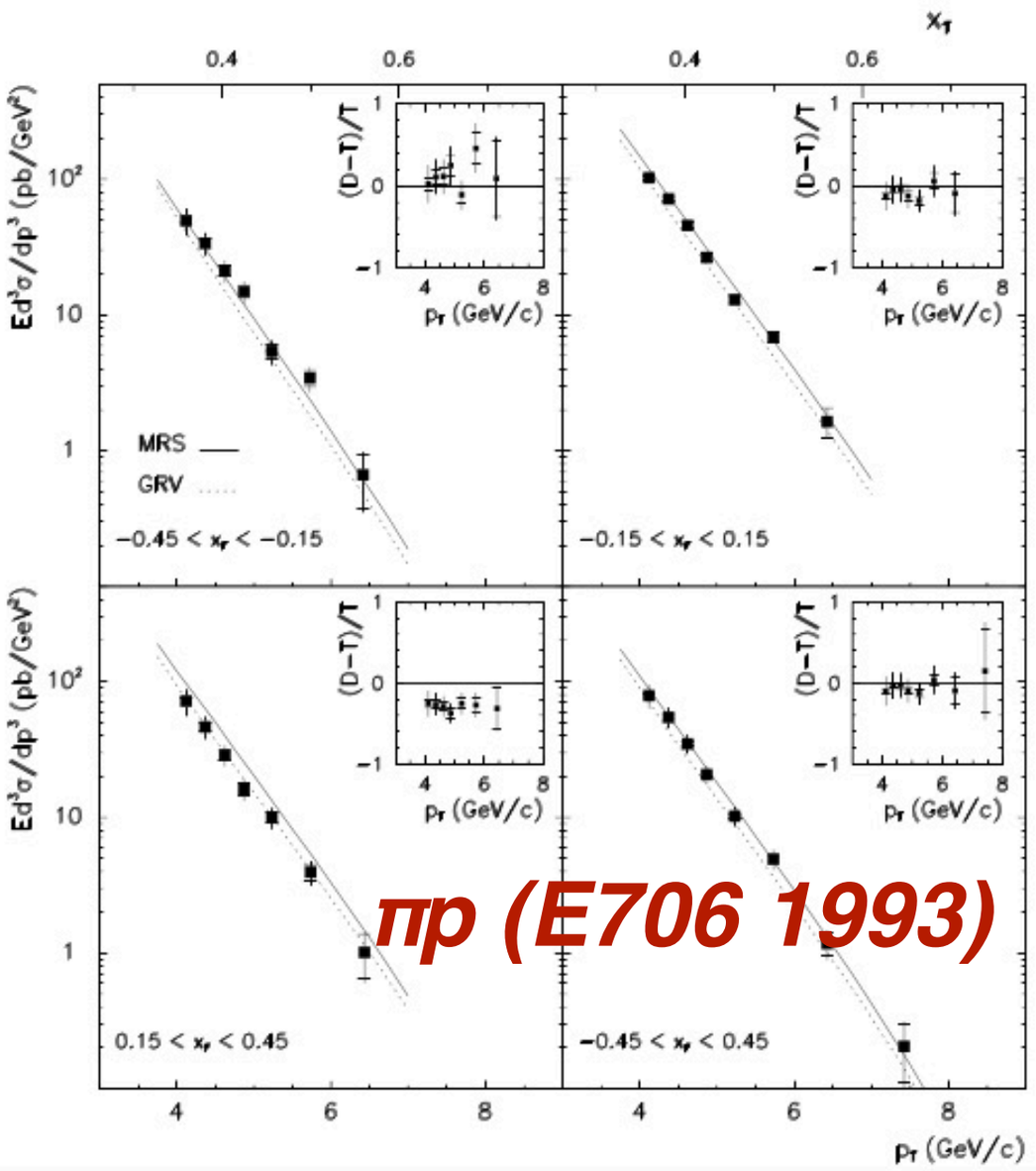
$$d\sigma_{AB} = \sum_{a,b=q,\bar{q},g} \int dx_a dx_b f_a^A(x_a,\mu^2) f_b^B(x_b,\mu^2) d\sigma_{ab\to\gamma X}(x_a,x_b,\mu^2).$$

access to gluon distributions in hadrons



pp(pbar)

$x_T = 2p_T/\sqrt{s}$

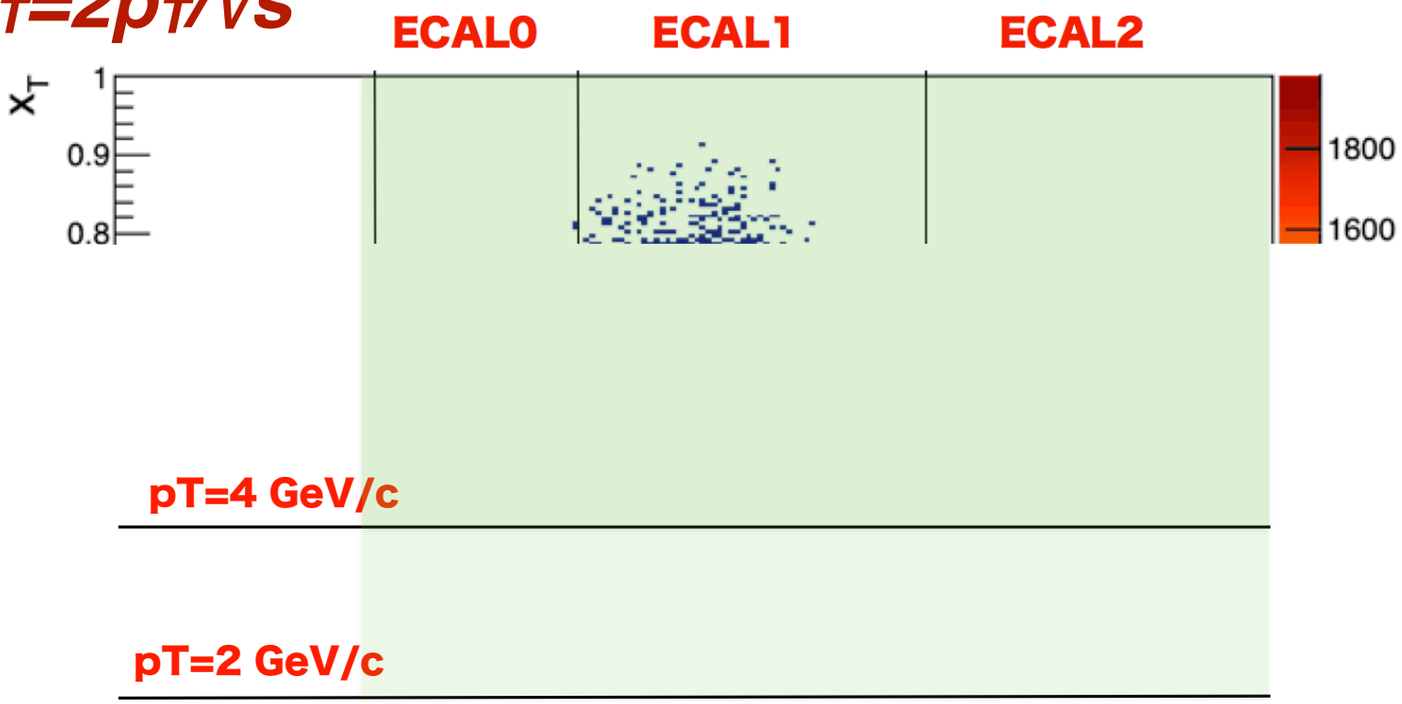


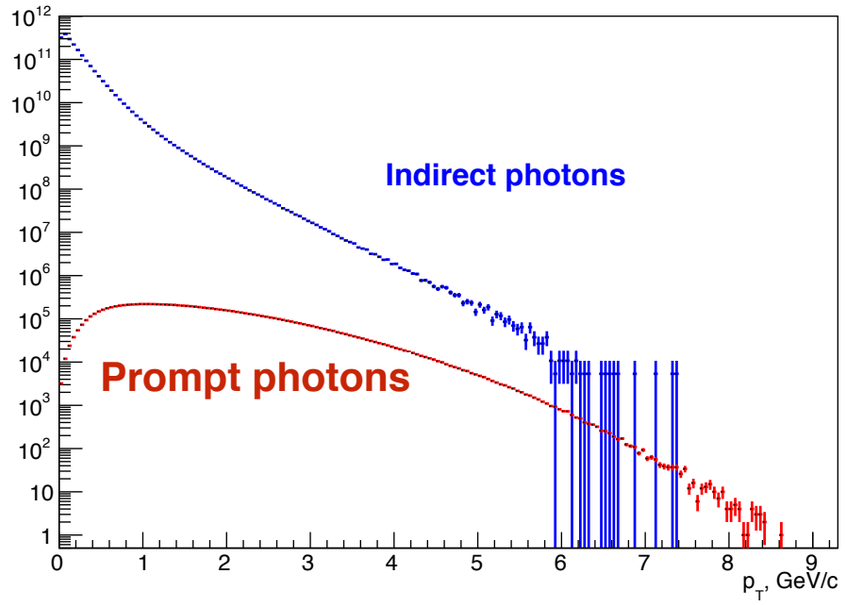
πp (E706 1993)

Kp - no results!

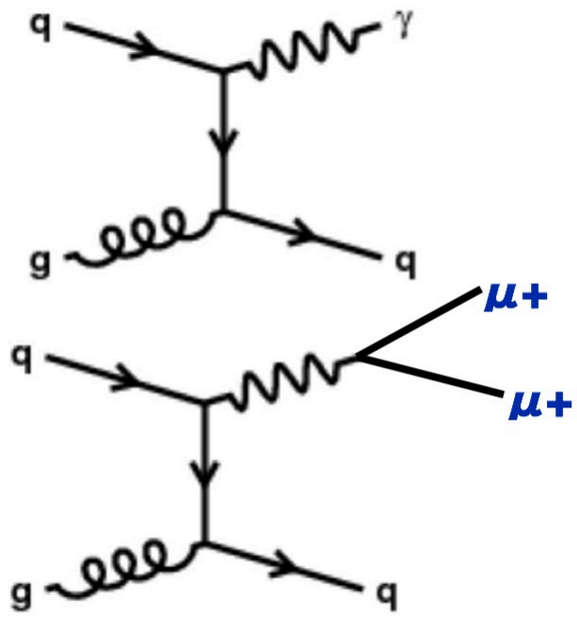
Prompt photons at COMPASS

$x_T = 2p_T/\sqrt{s}$





COMPASS with 3 electromagnetic calorimeters has unique chance to test gluon structure of protons, pions and kaons (also gluon EMC-effect)

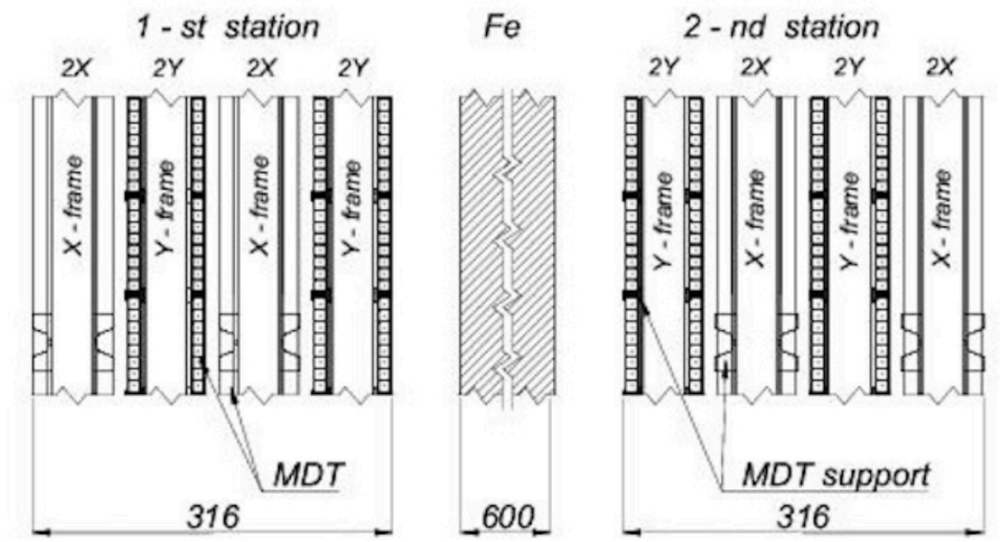


Prompt photons and low-mass dimuons - complementary measurement!

Upgrade of the COMPASS setup

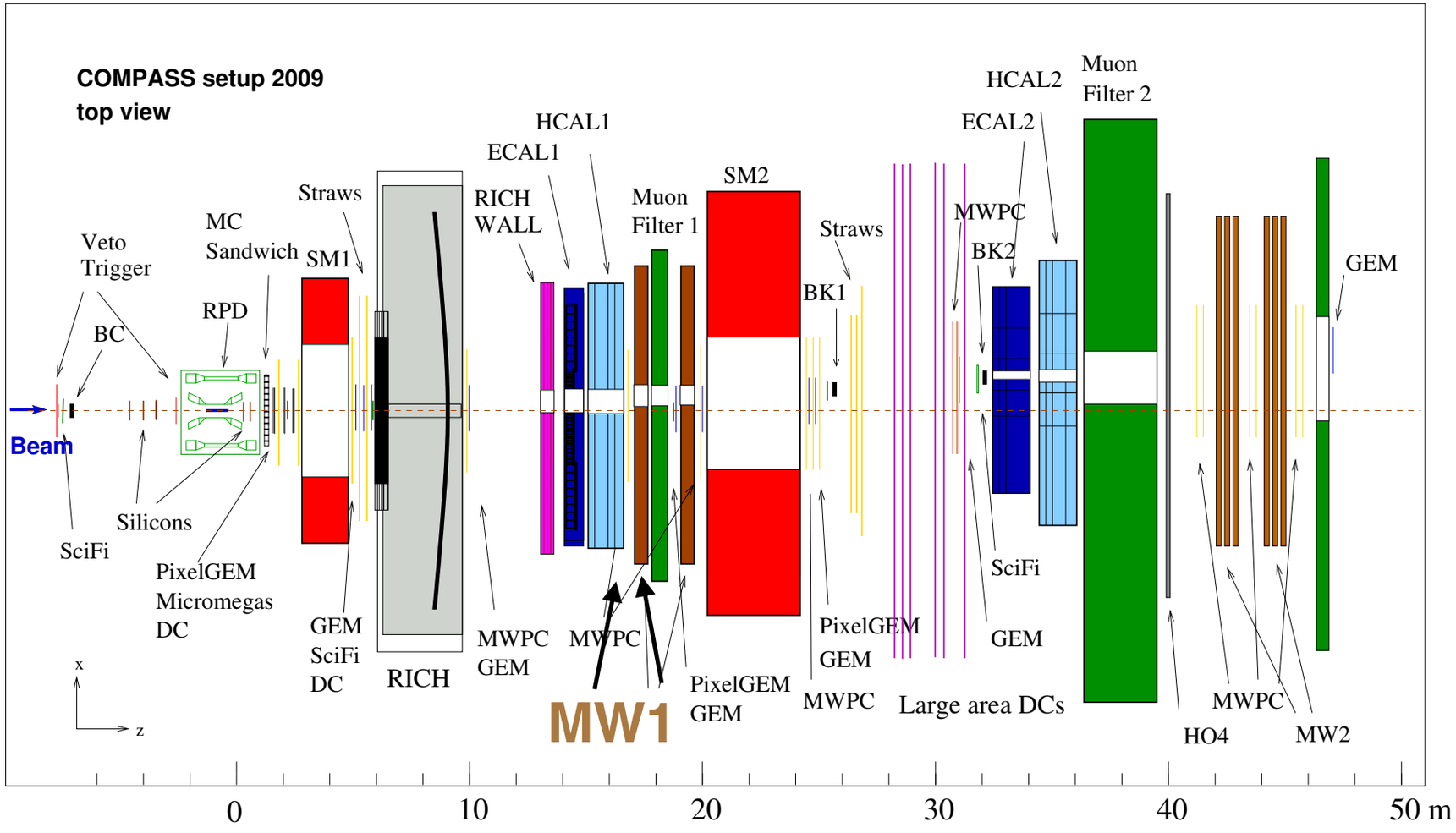
Preparation for MW1 upgrade

Muon Wall 1 - coordinate detectors (MDT) providing muon ID in the Large Angle Spectrometer



upgrade of HV, slow control, gas distribution system, revision of detecting elements

possibility to replace MDTs by another type detectors (GEM, Micromegas, RPC, …) should also be investigated



Plan for 2017-2019

2017

- Analysis of the data. Final result for X(3872) production.
- MC simulation of the prompt photons production and kaon-induced reactions.
- Participation in data taking.
- R&D for MW1, general revision of the existing detectors.

2018

- Analysis of the data. First results for pion polarisabilities from 2012 data, for EMC effect and $F_{3\pi}$ constant;
- Conclusions about feasibility of the proposed tasks for future program. Participation in preparation of the Proposal for the phase III of the experiment.
- Participation in data taking.
- R&D for MW1, preparation for MW1 upgrade.

2019

- Analysis of the data. Results for photoproduction of other exotic charmonia.
- Preparation for future program.
- Preparation for MW1 upgrade.

Funding request for 2017-2019

	Item	Total	2017	2018	2019
1	Personal computing	6	2	2	2
2	Travel expances including coverage of shifts, participation on the work of the collaboration, conferences and workshops	140	50	50	40
3	Materials and equipment for R&D and preparation for future upgrade of MW1	60	10	20	30
	Total, k$	206	62	72	72

SUMMARY

- ***The new separate project "Hadron Physics at the COMPASS Experiment" covers such topics as low-energy QCD with Primakoff reactions, EMC-effect in pion-induced Drell-Yan, photoproduction of exotic charmonia and participation in preparation of the physics program for the period 2020+***
- ***Main fields of activity of our group are: analysis of existing data, participation in collection of new data, MC simulation for future program, R&D and preparation for detector upgrade.***
- ***We ask PAC to approve our project for the period 2017-2019***