Production of open charm and tau leptons at the NICA SPD: phenomenology and simulation

Status report

Aleksandr Berezhnoy on behalf of MSU SPD group

October 25, 2023

VI SPD Collaboration Meeting, Samara University

Project tasks and participants

task	participant	role
Λ_c production	Alexandr Berezhnoy Evgeniy Leshchenko Leonid Seryogin Artem Smirnov	project leader student student student
di-ϕ production	Leonid Seryogin	student
τ pair production	Viacheslav Bunichev Aleksey Aleshko	senior reseacher postgraduate
DAQ front-end of RS creating a simulator of the first-level L1 concentrator for testing purposes for FDM-192 unit [1]	Andrey Ainikeev	senior reseacher

Project duration: 15.04.2023 – 15.10.2023

[1] See talk of Guennadi Alexeev, October 24,2023

Motivation

- An open charm production in proton-proton collisions at medium and low energy allows to study in detail heavy quark hadronization processes, as well as to better understand the proton structure.
- More recently, experiments LHCb and CMS observed structures in the spectrum of two J/ψ mesons, which with a high probability can be interpreted as $cc\bar{c}\bar{c}$ tetraquarks. Tetraquark states similar to those could be observed in other di-meson spectra, such as $\omega\omega$ and $\phi\phi$. There are theoretical indications that $f_0(2200)$ and $f_2(2340)$ may be candidates of $ss\bar{s}\bar{s}$ tetraquarks.
- Pair of τ carries information about polarisation state of initial partons Due to decay properties of τ lepton, it is possible to reconstruct polarisation state of τ through its decay products and there obtain information about the polarization of initial partons.

Λ_c production (I)

Signal

- ~ 12000 events have been generated within the Pythia8 framework using the hard subprocesses $gg \to c\bar{c}$ and $q\bar{q} \to c\bar{c}$
- The events with Λ_c^+ has been selected
- All Λ_c^+ baryons have been enforced to decay to $p^+K^-\pi^+$ combination
- $\Lambda_c^+ \to (\Delta^{++} \to p^+\pi^+)K^-$ has been temporary used instead of complete decay model due to the technical reasons

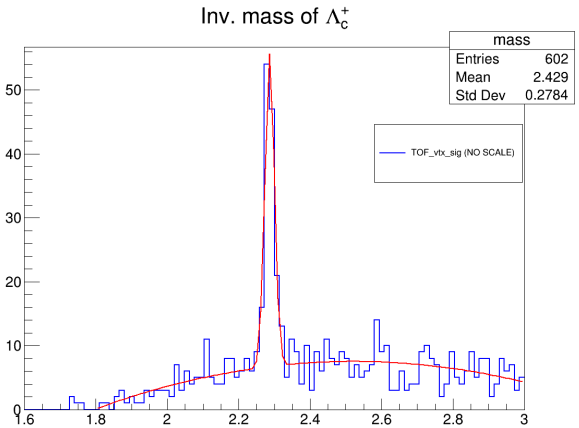
Background

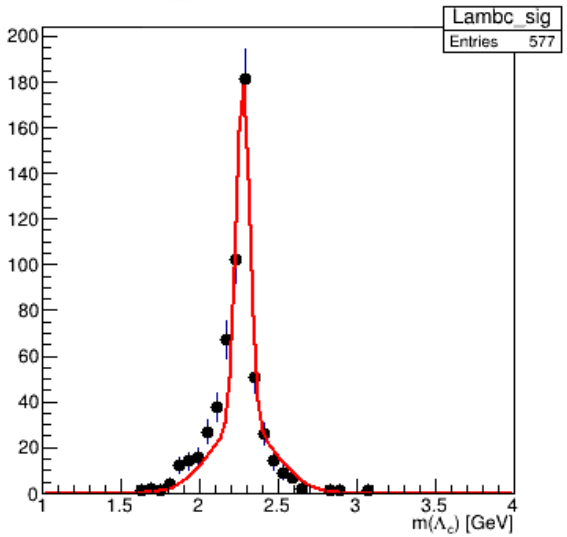
~ 25000 softQCD(MB) events have been simulated within Pythia8 as a background.

Detector simulation

SPDROOT

Λ_c production (II)





Number of events in the 3σ range

$$N_{sig} = 2.87067 \cdot 10^6$$

$$N_{bg} = 6.36848 \cdot 10^9$$

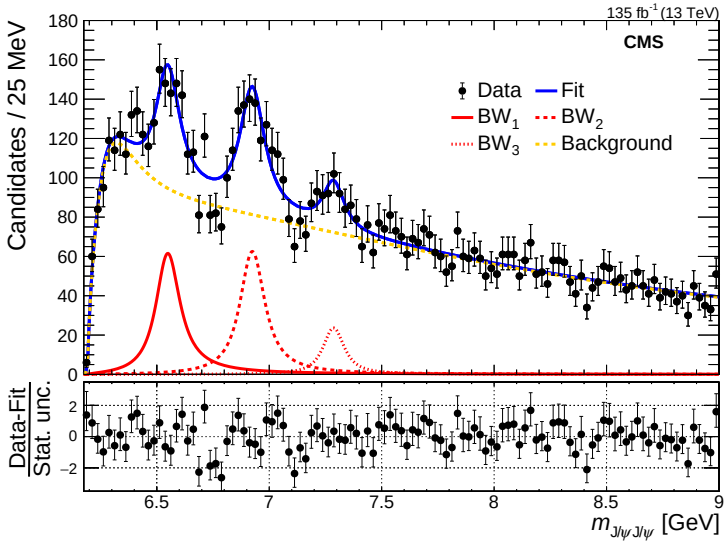
Signal significance

$$\frac{N_{sig}}{\sqrt{N_{bg}}} \sim 40$$

fitting

Detector resolution for Λ_c is asymmetric

di-ϕ (I)



CMS: $pp \to J/\psi J/\psi$

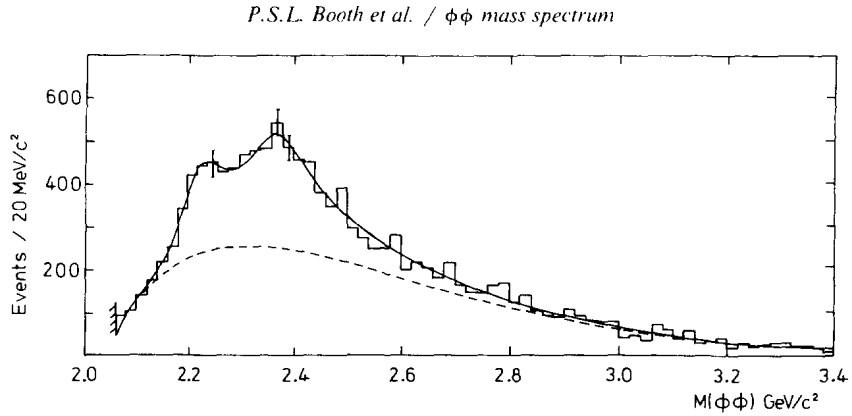
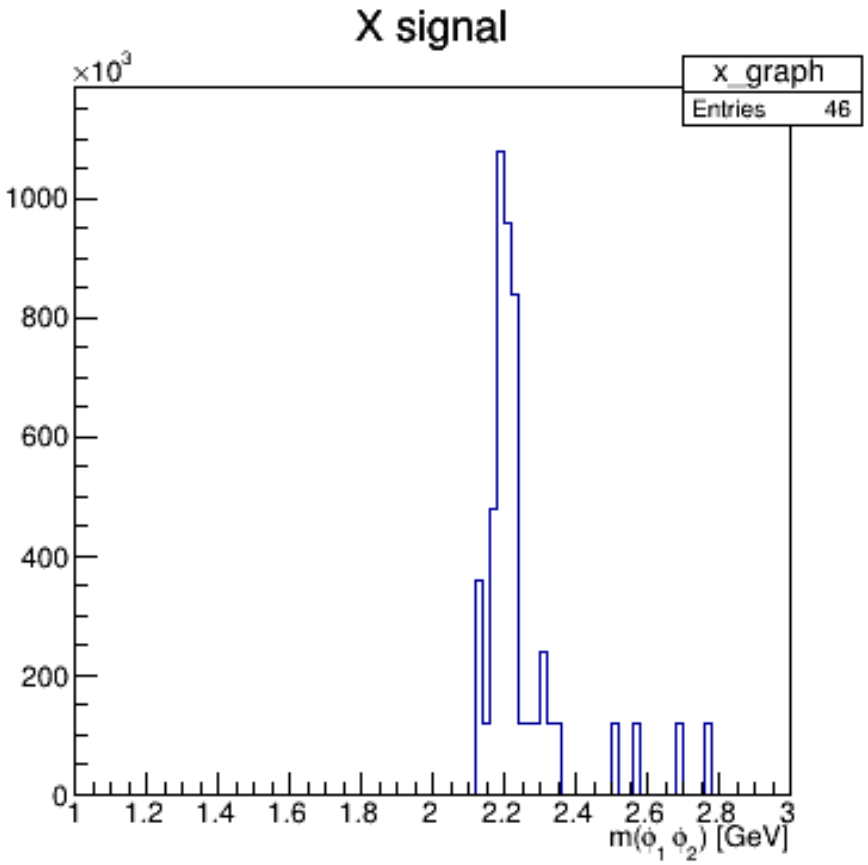


Fig. 6. The "true" $\phi\phi$ mass distribution with fitted Granet et al. background plus two Breit-Wigners.

WA67: $\pi^-_{85\ \mathrm{GeV}} Be \to \phi\phi + X$

di-ϕ (II)



SPD conditions

Luminosity: $10^{32}\ cm^{-2}s^{-1}$

Time: $10^{7}\ s$ (≈ 1 year of operation)

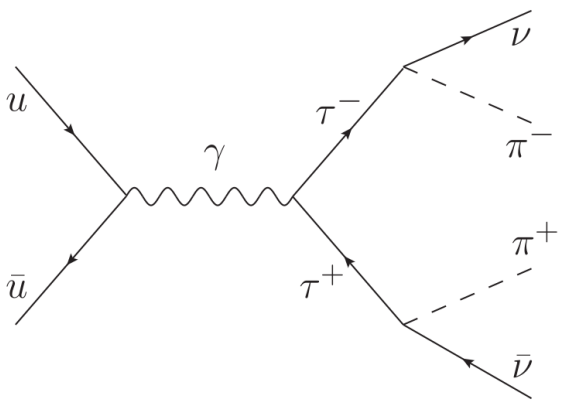
MB cross-section: 40 mb

di-ϕ cross section estimation

- J/ψ was modified and used as di-ϕ particle.
  The signal can be detected with 5 sigma significance if

$$\sigma_X \times \mathrm{Br}(X \to \phi\phi) \sim 30 \text{ nb}$$

τ pair production



Tool chain

LanHEP $\Rightarrow$ CompHEP $\Rightarrow$ Delphes $\Rightarrow$ Root

The obtained signal significance for 1 year of data taking at II stage of SPD is about 1.2σ.

Reports on SPD meetings

- Open charm at low eneries, October 10, 2023
- Tau signal on SPD, October 3, 2023
- Λ_c production simulation and di- ϕ production simulation within SPDRoot, September 26, 2023
- Λ_c^+ observation possibility at SPD NICA experiment, September 20, 2023

Results and parallel activities

Results

- It is shown that the Λ_c baryon can be studied in details at SPD.
- The minimum value of the production cross section of $\phi\phi$-system at which it should be observed in the SPD has been estimated.
- Production of τ leptons pairs is studied at LHCb. The significance 1.2σ is achieved.
- Two phenomenological papers are in preparation.

Parallel activities

- Artem Smirnov defended course work after the second year of MSU: Selection of events in the decay $\Lambda_b \to \Lambda_c 3\pi$ using BTDG.
- Evgeniy Leshchenko defended his Master's thesis and entered MSU graduate school.

Plans

- Two phenomenological papers will be publish:
  - the review on charm production at middle and low energies
  - the short paper on τ production.
- Leonid Seregin will defend his course work after the fourth year of MSU (former bachelor's thesis) on di-ϕ: di-ϕ + phenomenology.
- The selection procedure for $\Lambda_c \to pK\pi$ decay will improved.
- The decays $\Lambda_c \to \Lambda_0\pi$ and $\Lambda_c \to K_s p$ will be studied.
- single ϕ production will studied.
- PhD thesis of Evgeniy Leshchenko will be partially devoted to studies at SPD.

FYI

Leonid Gladilin joined the SPD MSU group!

ZEUS, ATLAS, open charm physics

Acknowledgements

We thank Igor Denisenko for help and fruitful discussion.

We thank JINR for the provided opportunity to make this research.

Thank you for your attention!