

Experimental Inputs for HVP by CMD-3

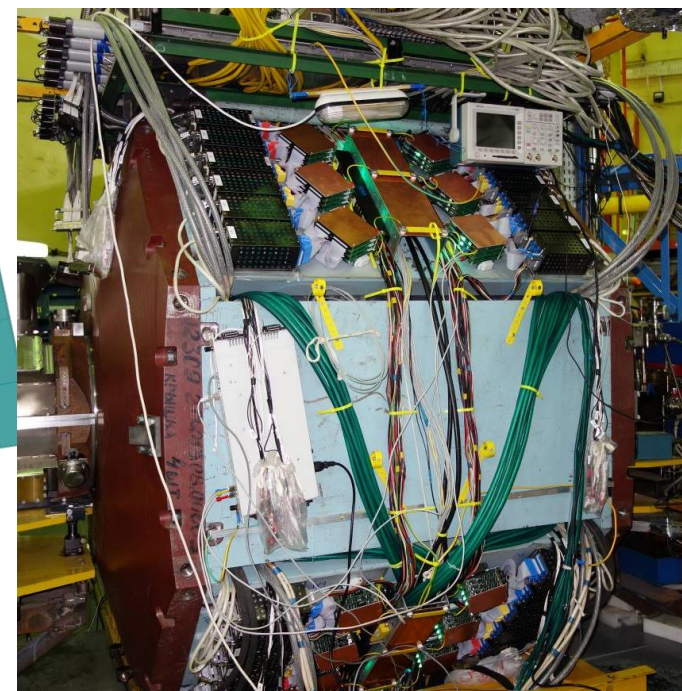
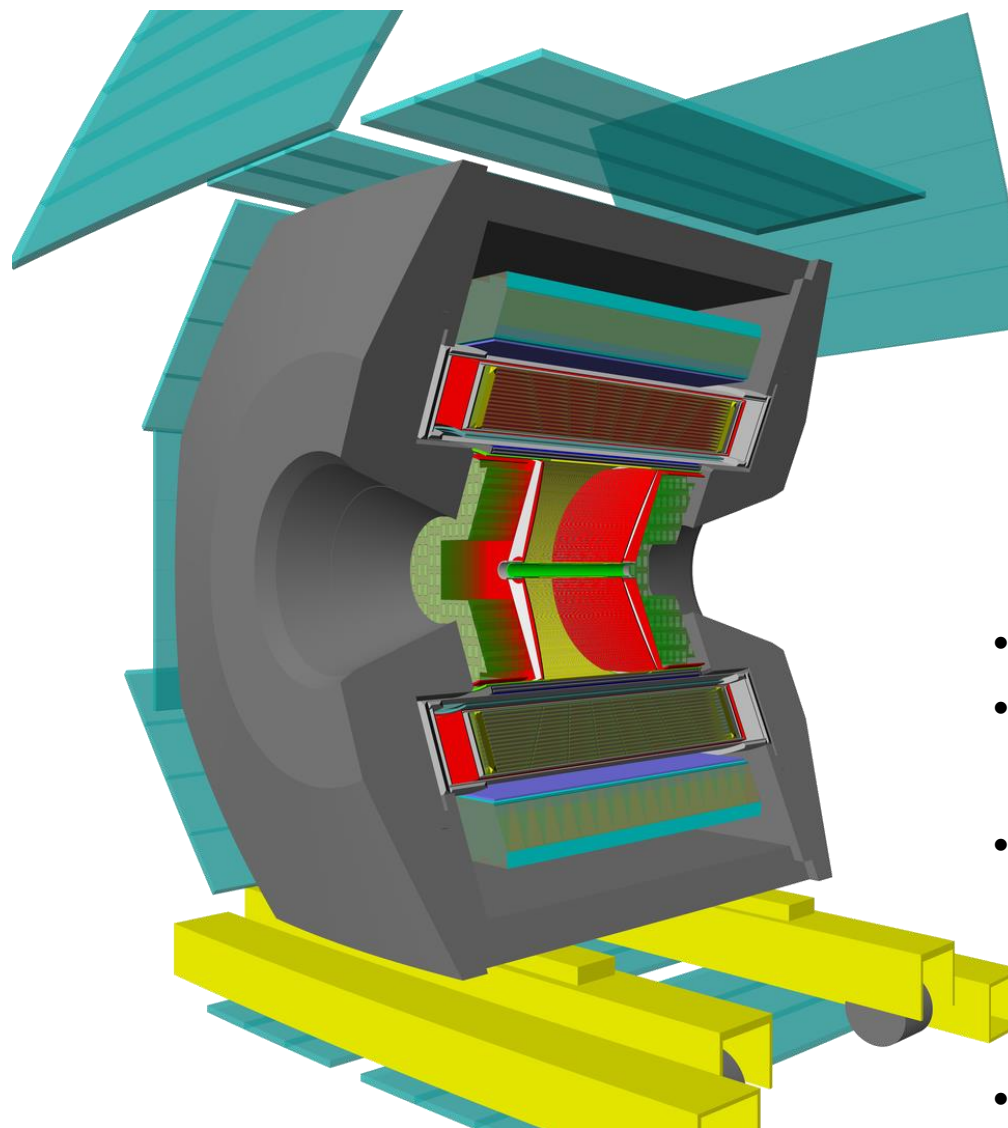
Ivan Logashenko (BINP) *on behalf of CMD-3 collaboration*

The Ninth
Plenary
Workshop of the
Muon $g-2$ Theory
Initiative

University of
Connecticut
(USA)

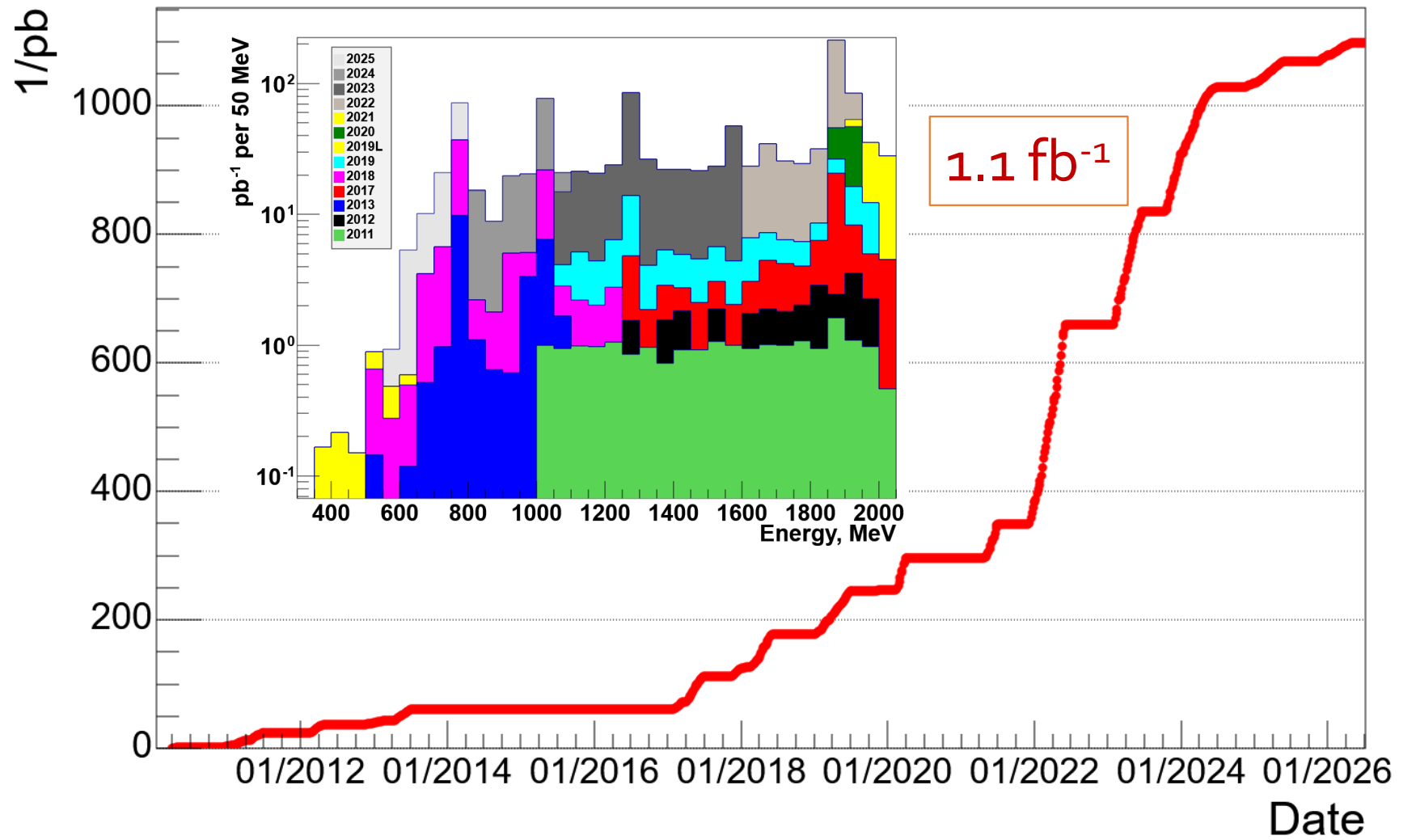
August 3-7, 2026

CMD-3 Detector



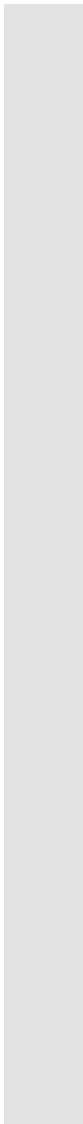
- Magnetic field 1.0-1.3 T
- Drift chamber
 - $\sigma_{R\phi} \sim 100 \mu, \sigma_z \sim 2 - 3 \text{ mm}$
- EM calorimeter (LXE, CsI, BGO), $13.5 X_0$
 - $\sigma_E/E \sim 3\% - 10\%$
 - $\sigma_\theta \sim 5 \text{ mrad}$
- TOF
- Muon counters

Collected data

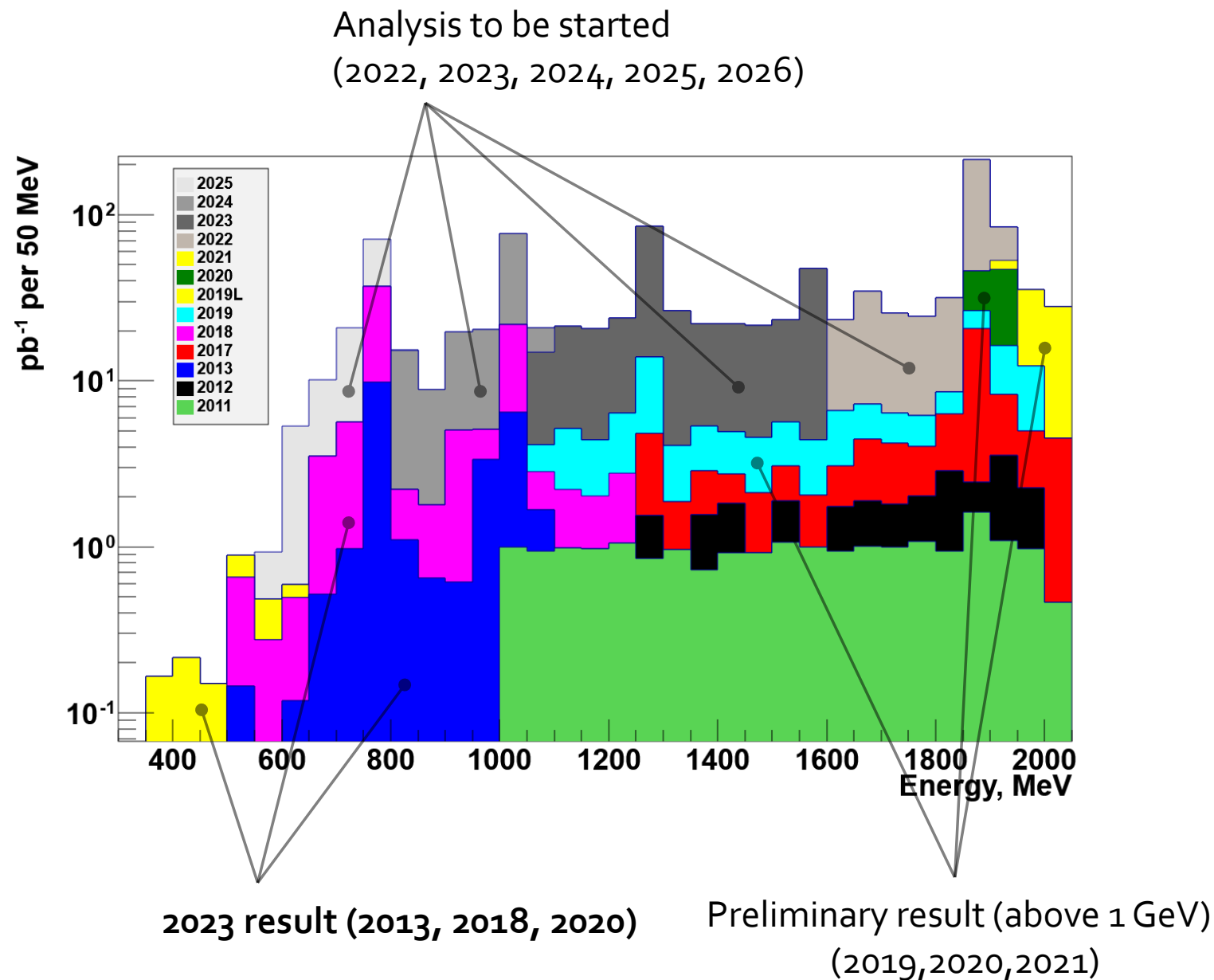


final states
under analysis

Signature	Final states (preliminary , published)
2 charged	$\pi^+\pi^- , K^+K^- , K_S K_L , p\bar{p}$
2 charged + γ 's	$\pi^+\pi^-\gamma , \pi^+\pi^-\pi^0 , \pi^+\pi^-\eta , K^+K^-\pi^0 , K^+K^-\eta , K_S K_L \pi^0 ,$ $K_S K_L \eta , \pi^+\pi^-\pi^0\eta , \pi^+\pi^-\pi^0\pi^0\eta , \pi^+\pi^--2\pi^0 , \pi^+\pi^--3\pi^0 ,$ $\pi^+\pi^--4\pi^0 , ...$
4 charged	$\pi^+\pi^-\pi^+\pi^- , K^+K^-\pi^+\pi^- , K_S K^\pm \pi^\mp$
4 charged + γ 's	$\pi^+\pi^-\pi^+\pi^-\pi^0 , \pi^+\pi^-\eta , \pi^+\pi^-\omega , \pi^+\pi^-\pi^+\pi^-\pi^0\pi^0 ,$ $K^+K^-\eta , K^+K^-\omega$
6 charged	$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^- , K_S K^\pm \pi^\mp \pi^+\pi^- , K_S K_S \pi^+\pi^-$
6 charged + γ 's	$3(\pi^+\pi^-)\pi^0$
Neutral	$\pi^0\gamma , \eta\gamma , \pi^0\pi^0\gamma , \pi^0\eta\gamma , \pi^0\pi^0\pi^0\gamma , \pi^0\pi^0\eta\gamma$
Other	$n\bar{n} , \pi^0 e^+e^- , \eta e^+e^-$
Rare decays	$\eta' , D^*(2007)^0 , f_1(1285)$


$$e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}$$

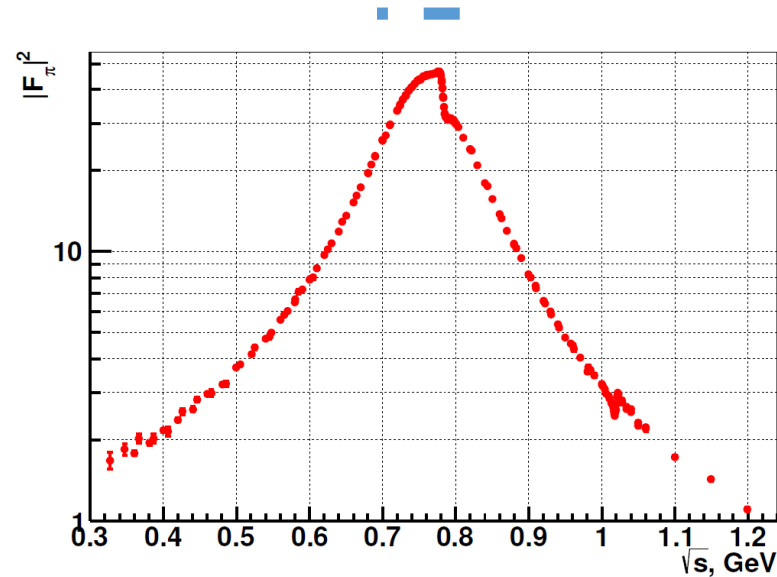
$e^+e^- \rightarrow \pi^+\pi^-$
data



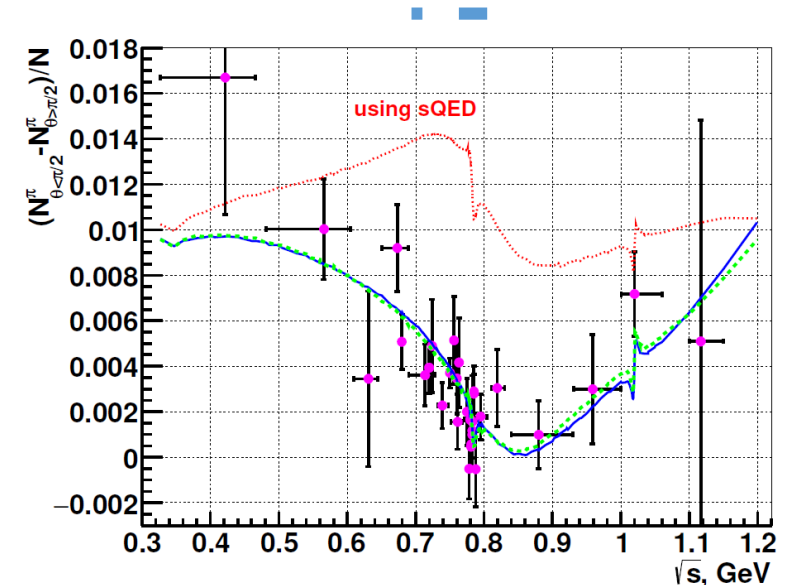
Reversed beams

In 2025 data at $\sqrt{s}$ from 0.76 to 0.81 GeV and at 0.70 GeV was taken with electron and positron beams circulating in opposite direction relative to usual data taking.

The goal is to perform the additional systematic studies of uncertainties related to angular distributions



Pion formfactor

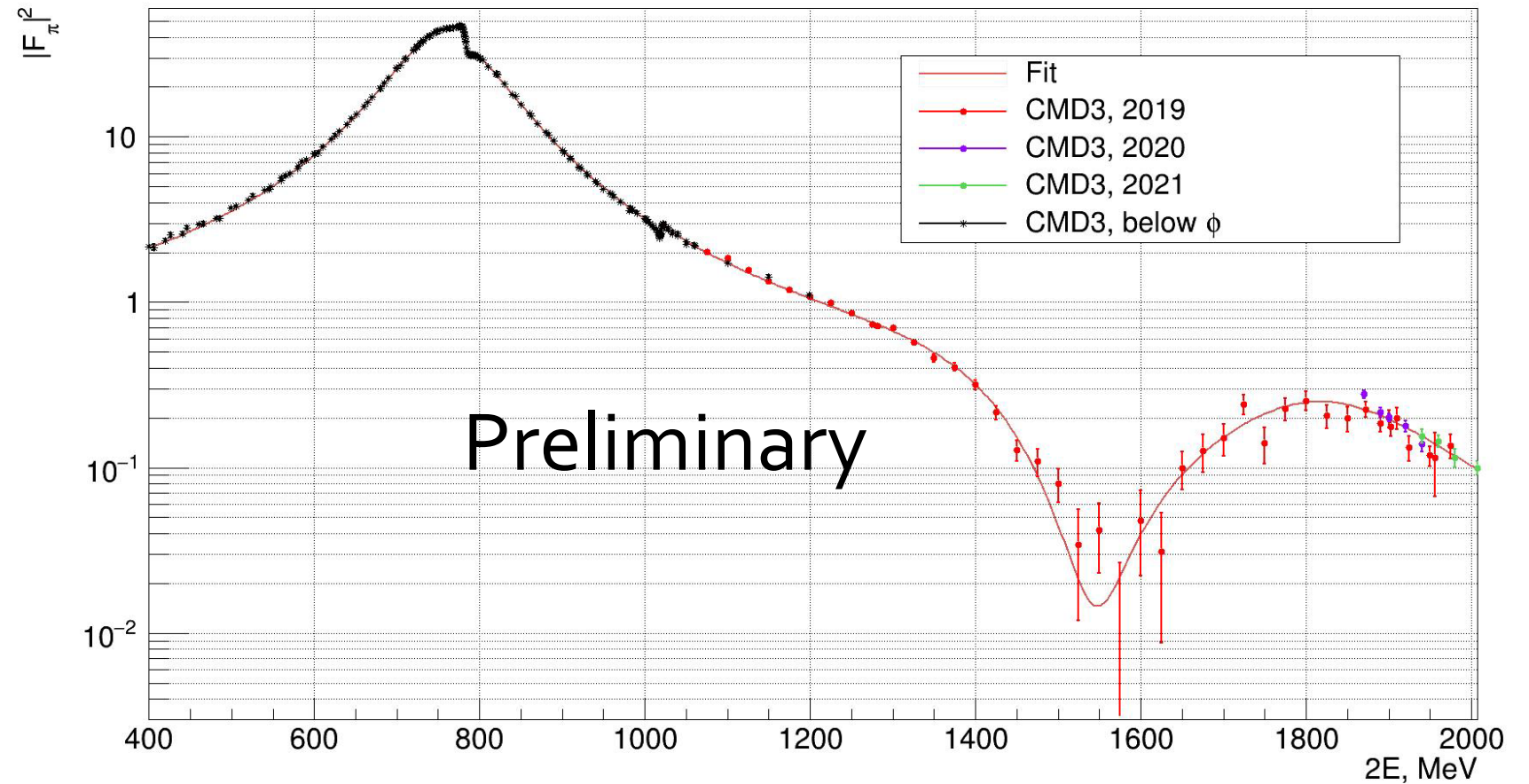


Charge asymmetry

2019-2021
analysis

Intermediate/
preliminary
result

Analysis is halted at the moment (no manpower)



Estimated systematic error
(preliminary)

0.8%

7%

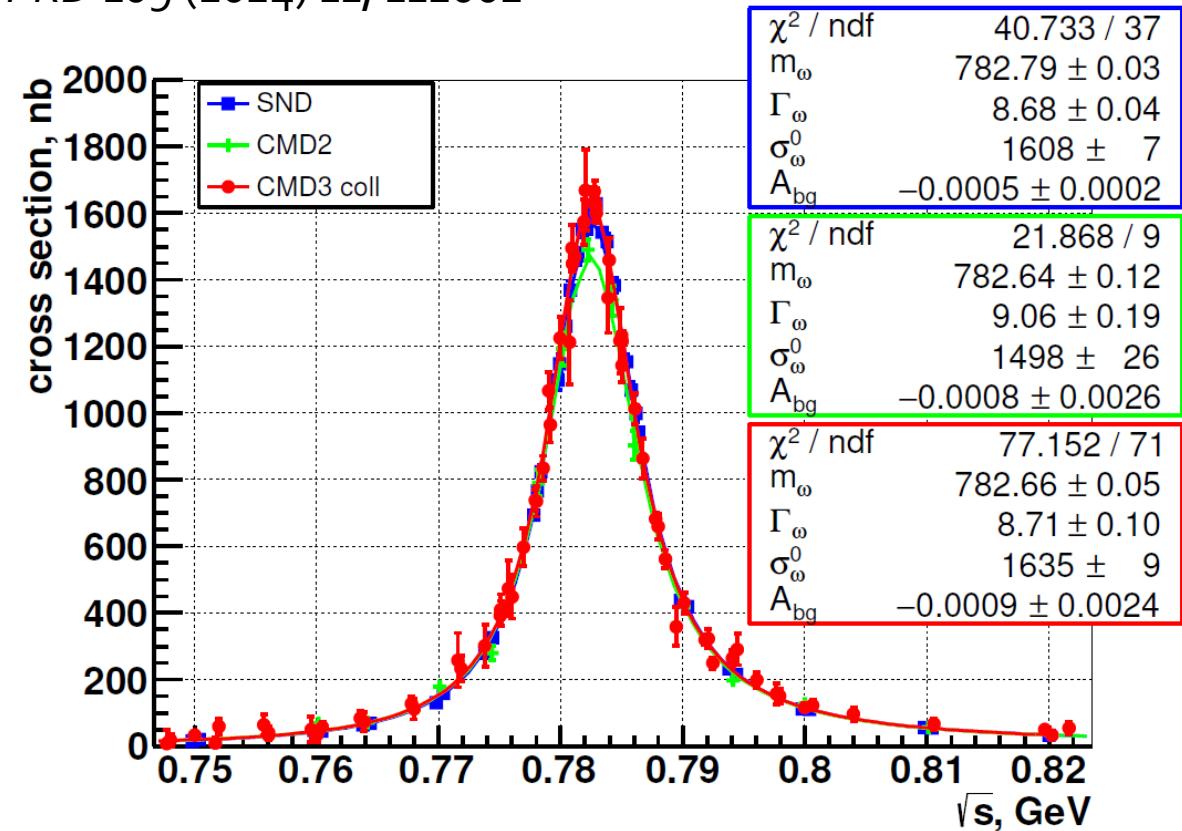
There are x4-5 more data in 2022-2024

Preliminary and new results

$e^+e^- \rightarrow 3\pi$ CMD-3 published result

$$\sigma(e^+e^- \rightarrow \pi^+\pi^-\pi^0) \text{ CMD-3 (2023)}$$

PRD 109 (2024) 11, 112002



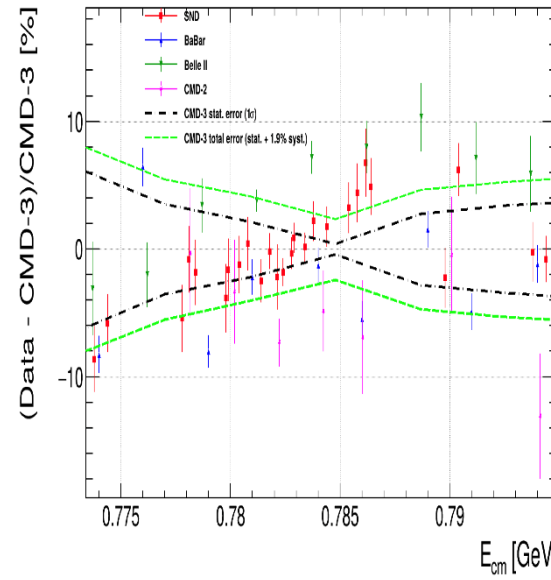
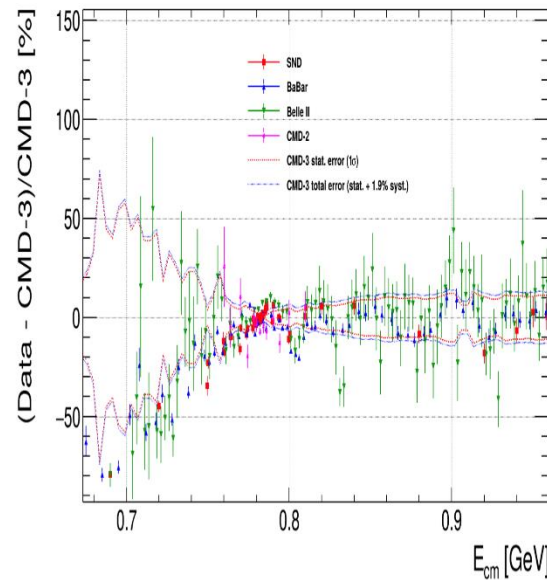
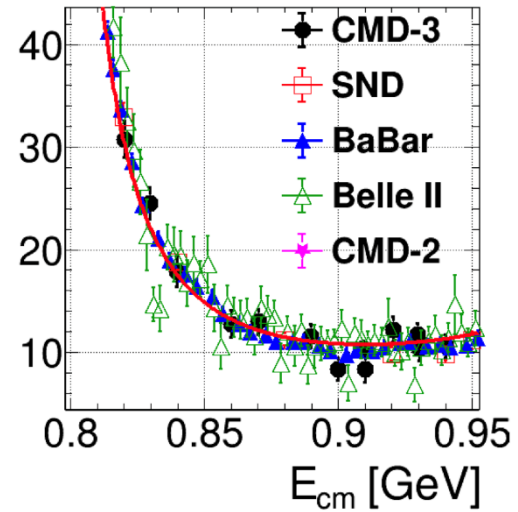
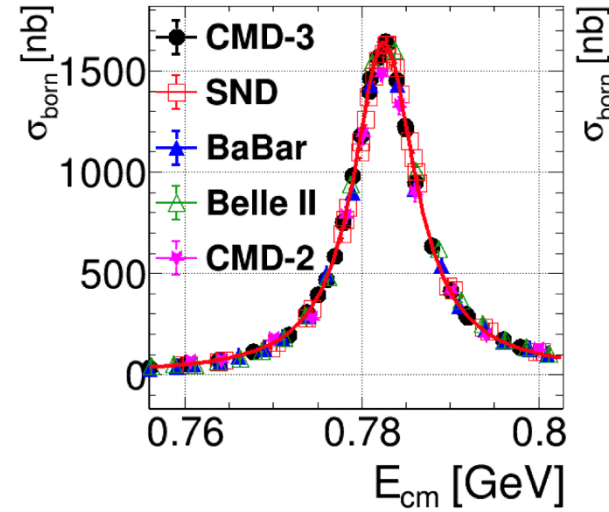
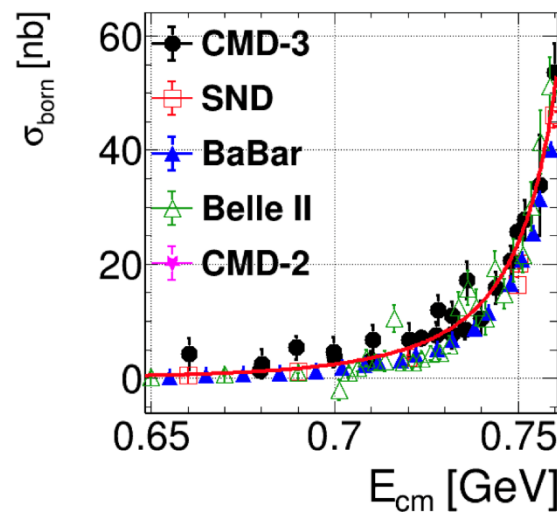
By-product of $e^+e^- \rightarrow \pi^+\pi^-$ analysis

Based on small subset of $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ sample ("collinear" selection cuts, π^0 nearly at rest)

Estimated systematic error is 3.3%

2.2 σ tension with CMD-2 measurement

$e^+e^- \rightarrow 3\pi$ CMD-3 dedicated analysis



- $E_{c.m.} = 0.66 - 0.97 \text{ GeV}$
- $L_{int} \approx 51.4 \text{ pb}^{-1}$
(2013, 2018)
- $N_{3\pi} \approx 480k$
- Estimated systematic uncertainty $\sim 1.9\%$

Collected extra 90 pb^{-1} in the same energy range – to be included in analysis

Publication in mid-2027 ?

CMD-3 measurements of $K_S K_L$

CMD-3 published $K_S K_L, K^+ K^-$ at $\varphi(1020)$

$e^+ e^- \rightarrow K^+ K^-$ PLB 779 (2018) 64

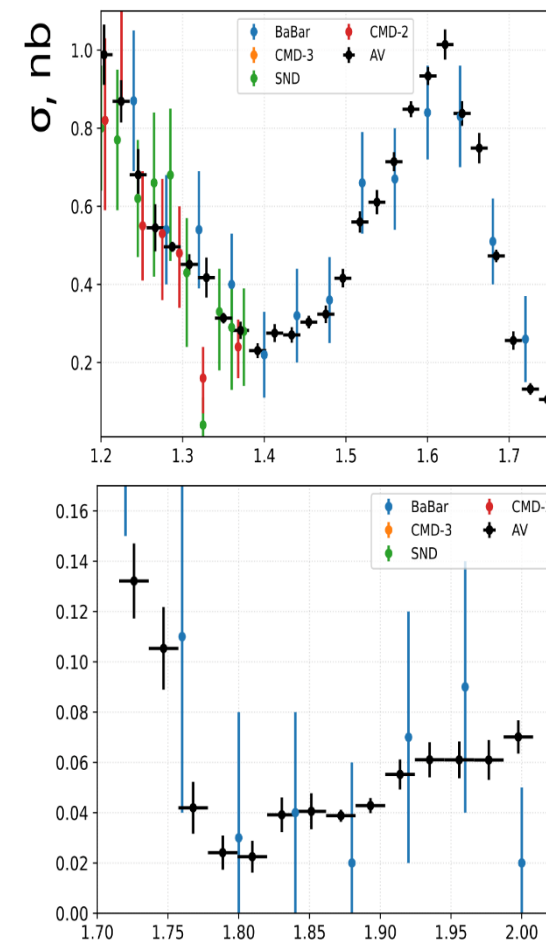
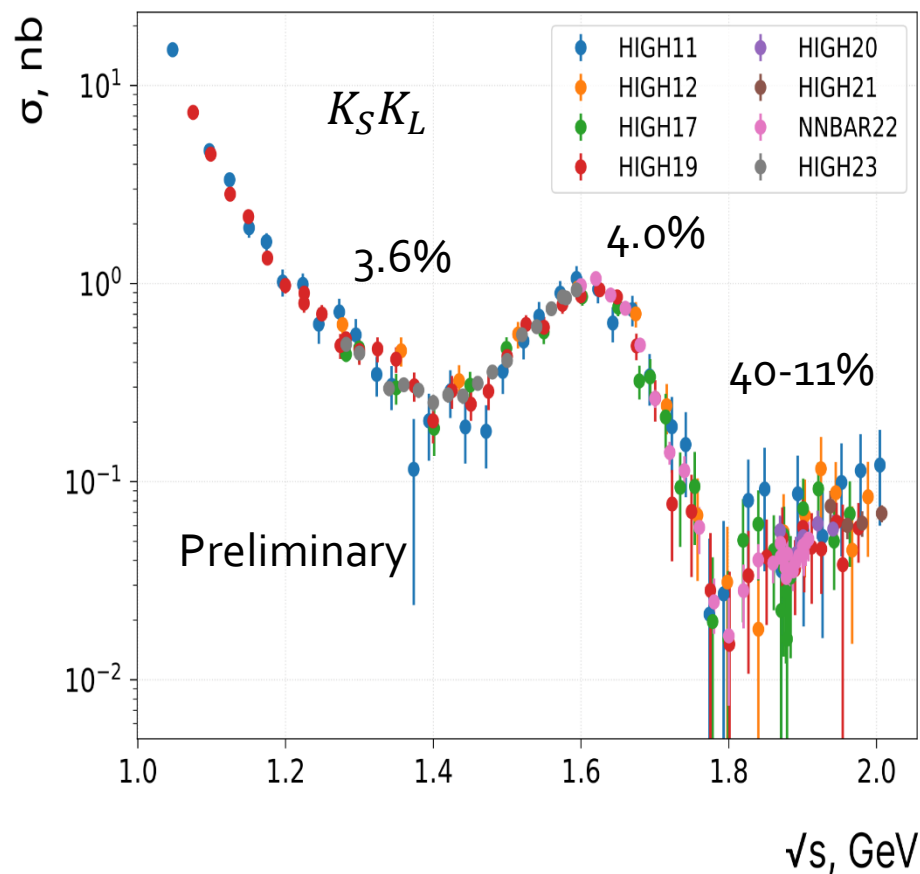
2.0% systematic error
(2.8% at high energy tail)

$e^+ e^- \rightarrow K_S K_L$ PLB 760 (2016) 314

1.8% systematic error

The $K_S K_L$ data analysis at energies above φ is considered finished.
Paper is in preparation.

20 MeV bins



Combined analysis of $K_S K_L$ and $K^+ K^-$

Missing ϕ'' is found!

PRELIMINARY Paper is in preparation

$K^+ K^-$ above φ is only preliminary

$$\sigma_{K_S K_L / K^+ K^-} = \frac{\pi \alpha^2 \beta^3}{3s} |F_{K^0 / K^\pm}|^2$$

$$F_{K^0 / K^\pm} = F_{I=0} \mp F_{I=1}$$

$$F_{I=0} = \frac{\lambda_0}{s} + \sum_m c_m e^{i\phi_m} \text{BW}(s, M_m, \Gamma_m)$$

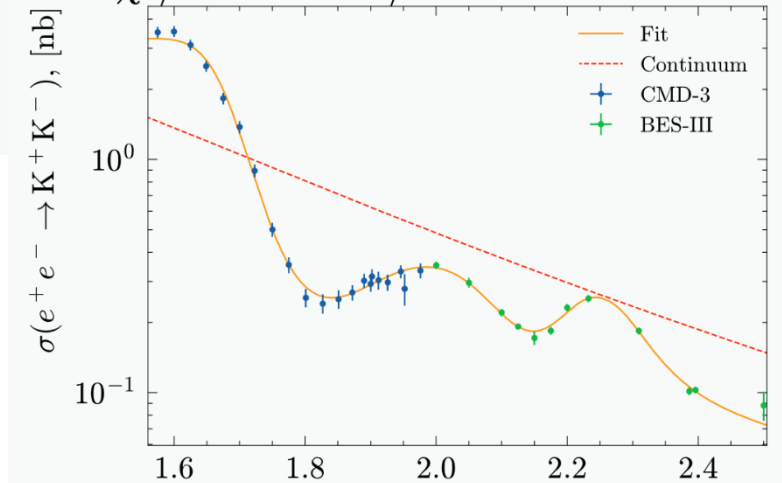
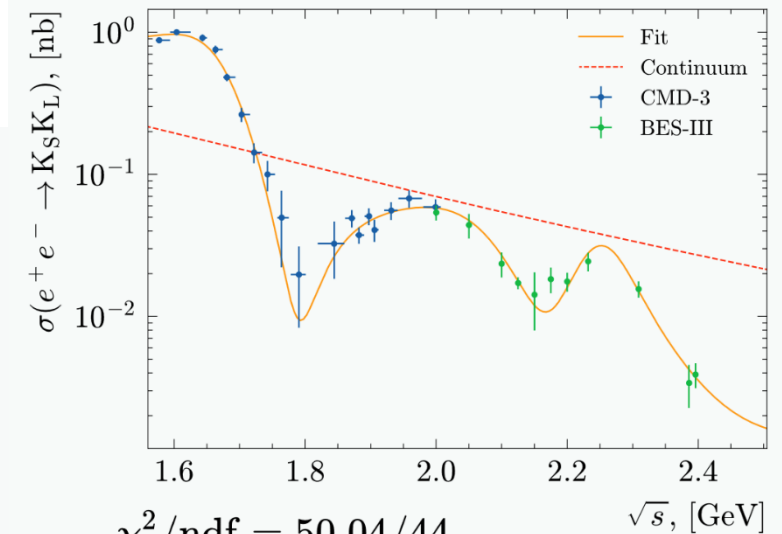
$$F_{I=1} = \frac{\lambda_1 e^{i\phi_1}}{s} + \sum_n c_n e^{i\phi_n} \text{BW}(s, M_n, \Gamma_n)$$

Fixed

- ρ'' (M=1821 MeV, Γ =316 MeV)
- ρ''' (M=2270 MeV, Γ =116 MeV)
- φ''' (M=2239 MeV, Γ =140 MeV)

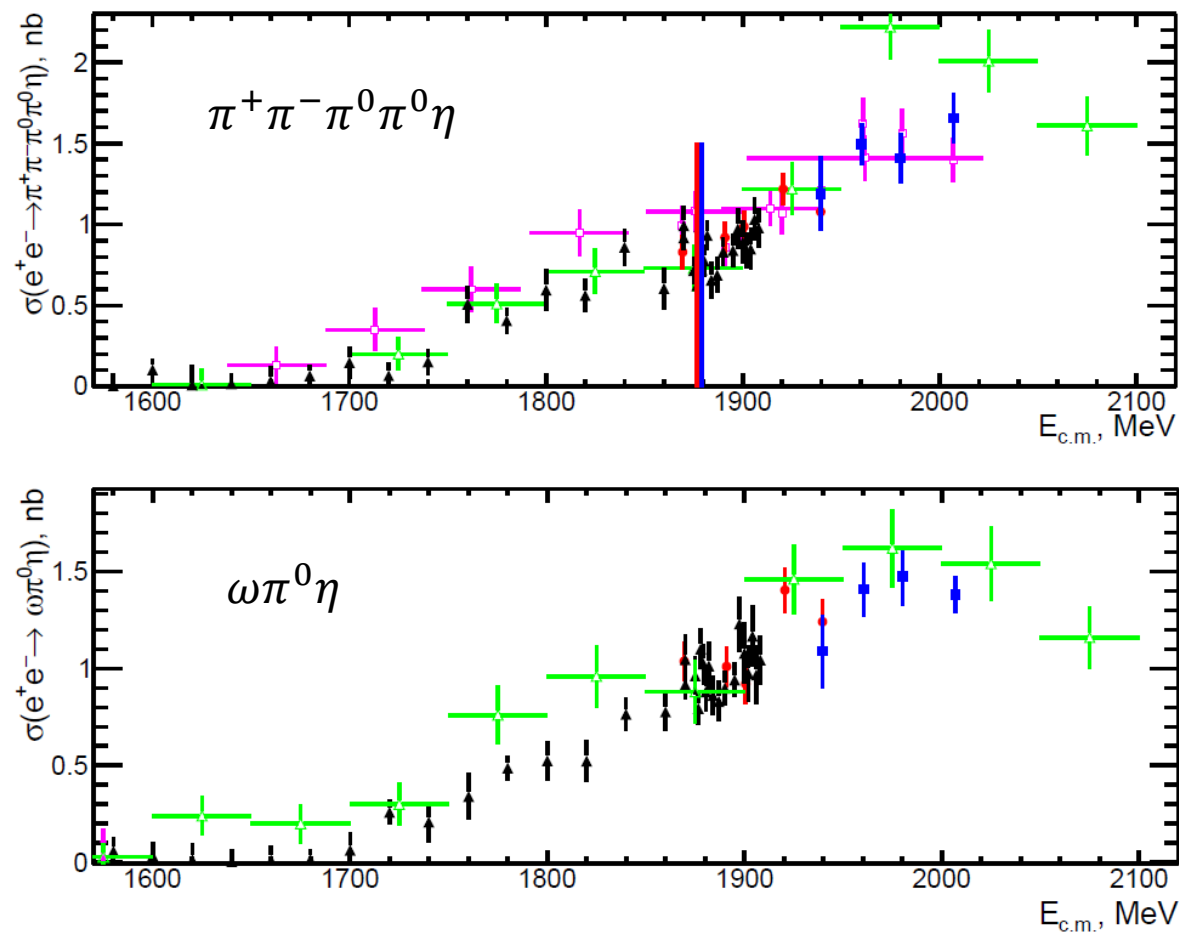
Free

- | | | |
|---|---|---|
| <ul style="list-style-type: none"> • φ' (M~1680 MeV, Γ~150 MeV) • φ'' (M~2000 MeV, Γ~250 MeV) | → | <ul style="list-style-type: none"> • φ' (1.672±0.006 GeV, 0.179±0.011 GeV) • φ'' (2.073±0.022 GeV, 0.281±0.030 GeV) |
|---|---|---|



$$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0\eta$$

New result – paper is submitted to JHEP, arXiv:2607.11556



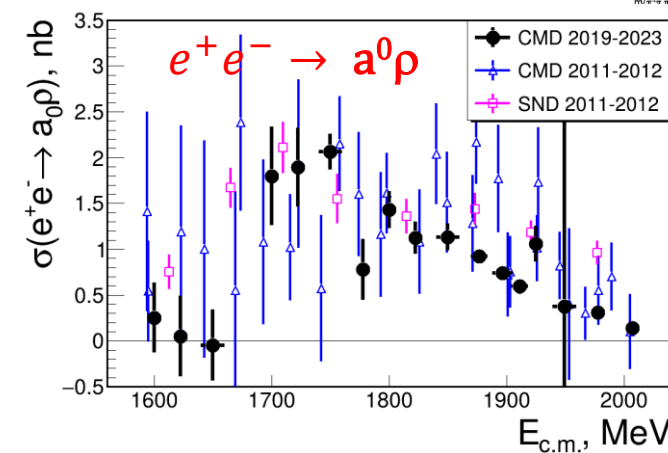
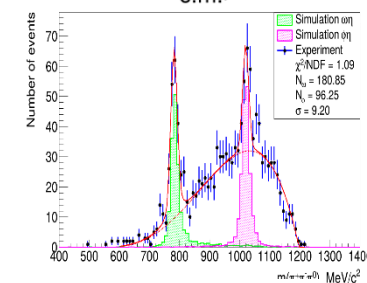
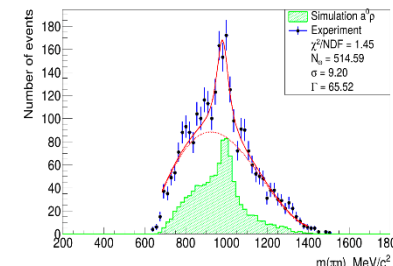
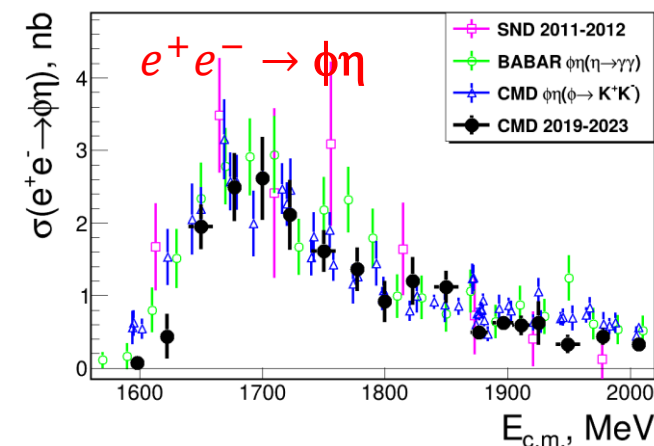
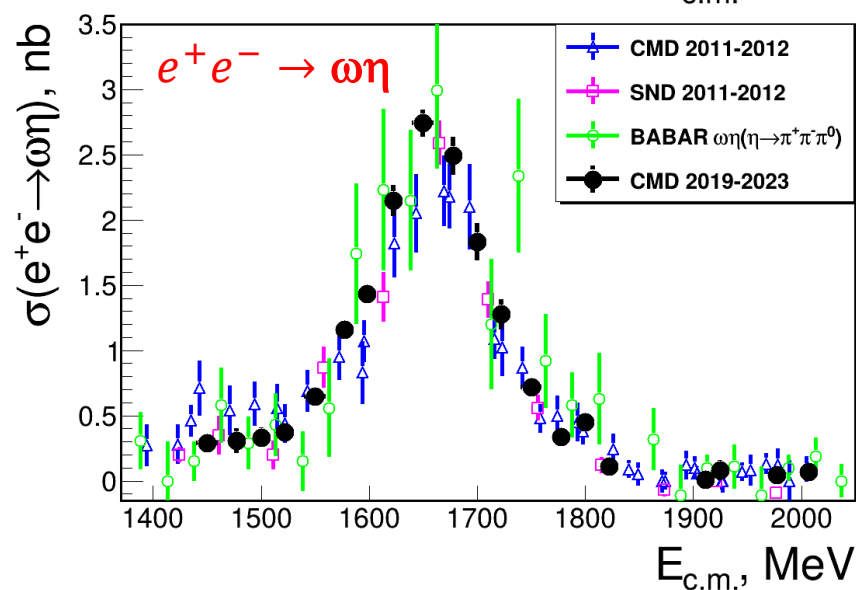
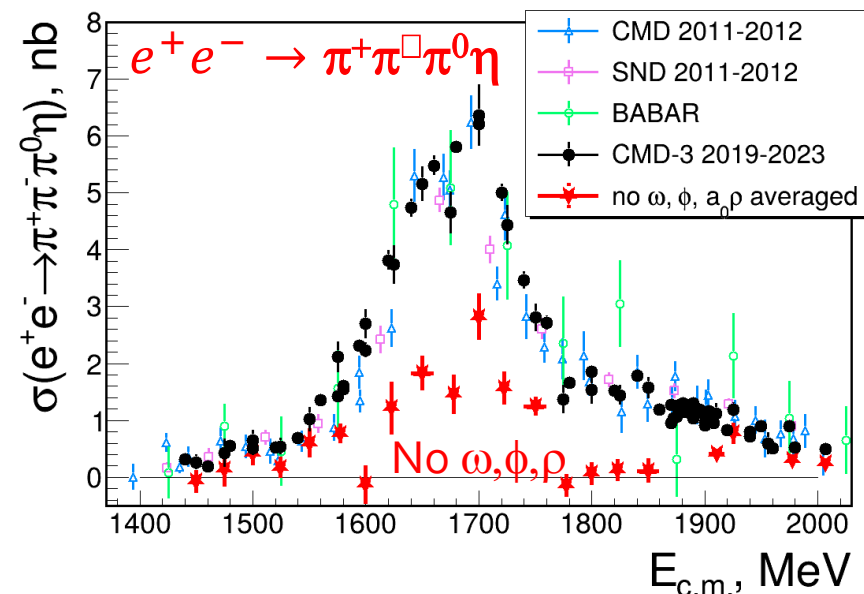
- 2020-2022 data
- 372 1/pb
- ~6300 events
- 8-10% systematics

Comparison with
the BaBar and SND
measurements
(green and purple)

PRELIMINARY

$$e^+e^- \rightarrow \pi^+\pi^-\pi^0\eta$$

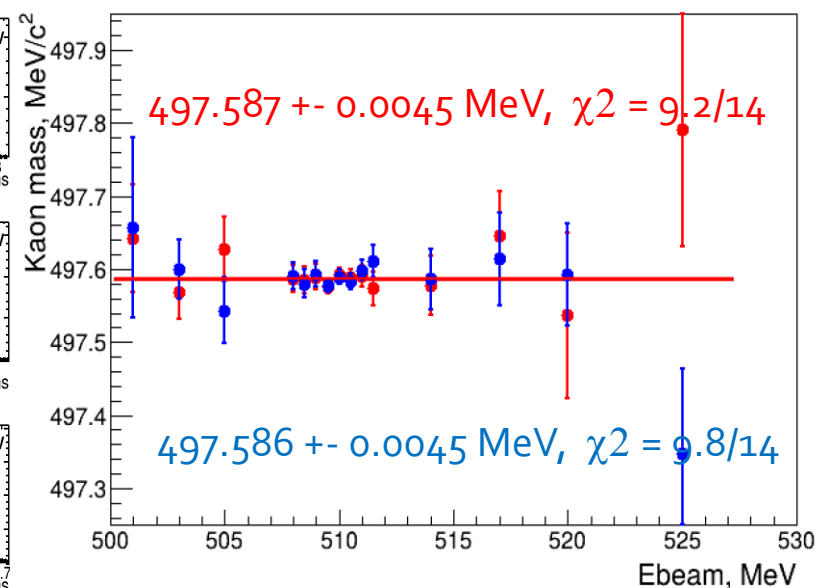
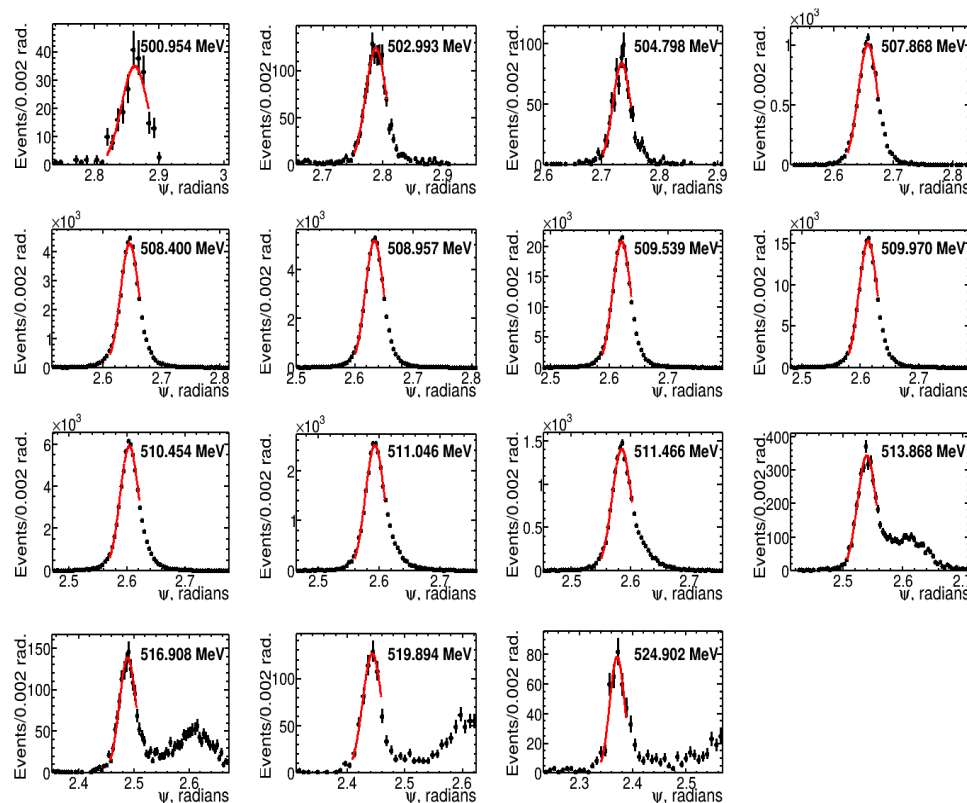
Previous study was published based on 21 pb^{-1} (PLB 773 (2017) 150).
Now we use 482 pb^{-1}



Using edge angle approach for 15 points around ϕ -resonance,
and a calibration by the PDG ϕ -resonance mass we obtaine:

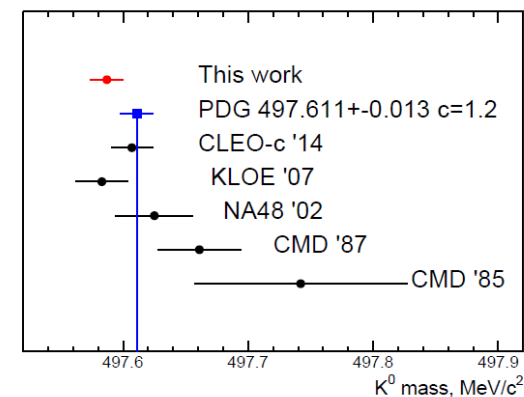
$$m(K^0) = 497.587 \pm 0.004(\text{stat}) \pm 0.009(\text{syst.calbr}) \pm 0.008(\text{syst.cmd}), \text{ MeV}/c^2$$

New K^0 mass measurement



$$m(K^0) = 497.587 \pm 0.004(\text{stat.}) \pm 0.012(\text{syst.})$$

Paper is submitted to JHEP, arXiv:2606.16779

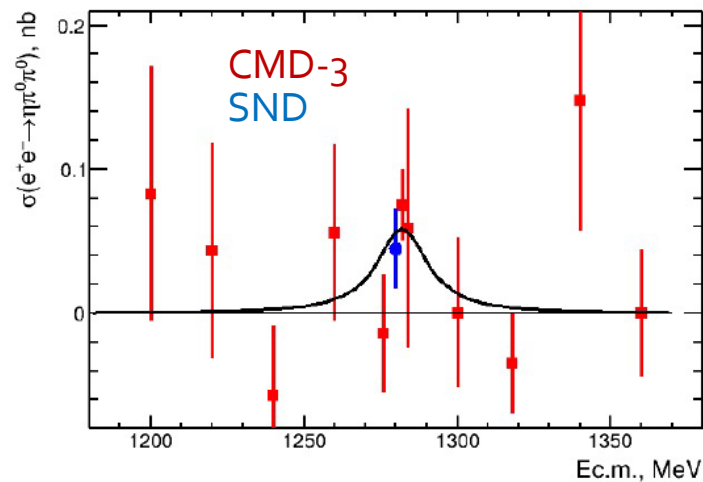


$$e^+e^- \rightarrow f_1(1285)$$

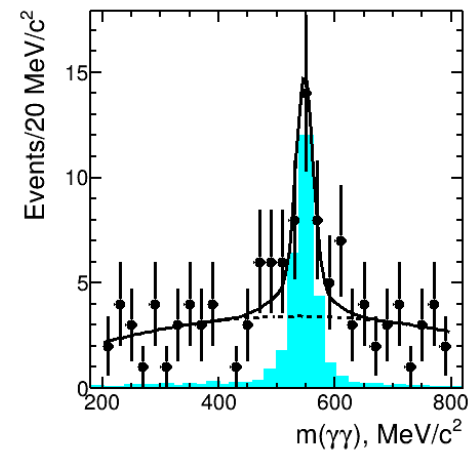
Search for $e^+e^- \rightarrow f_1(1285)$ - interesting for LBL!

Was previously reported by SND (PLB 800 (2020) 135074)

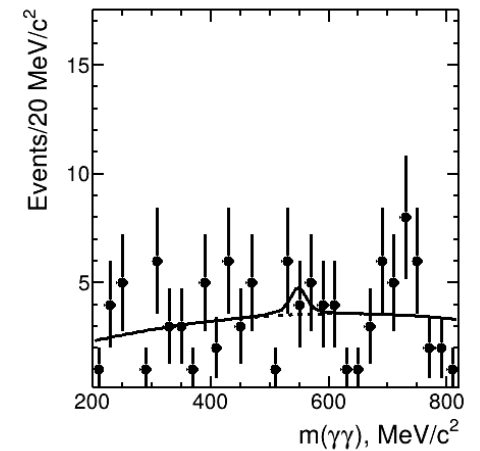
Decay mode $f_1 \rightarrow \eta\pi^0\pi^0 \rightarrow \gamma\gamma\pi^0\pi^0 \rightarrow 6\gamma$



Cross section



Signal region



Sideband

$$B(f_1(1285) \rightarrow e^+e^-) = (8.3 \pm 2.3 \pm 1.1) \times 10^{-9} \text{ (preliminary)}$$

Paper is about to be submitted

Next round of experiments

VEPP-2000 /CMD-3 plans

We plan to do major redesign of CMD-3 with the goal to reach $\sim 0.2\%$ in $\sigma(e^+e^- \rightarrow \pi^+\pi^-)$

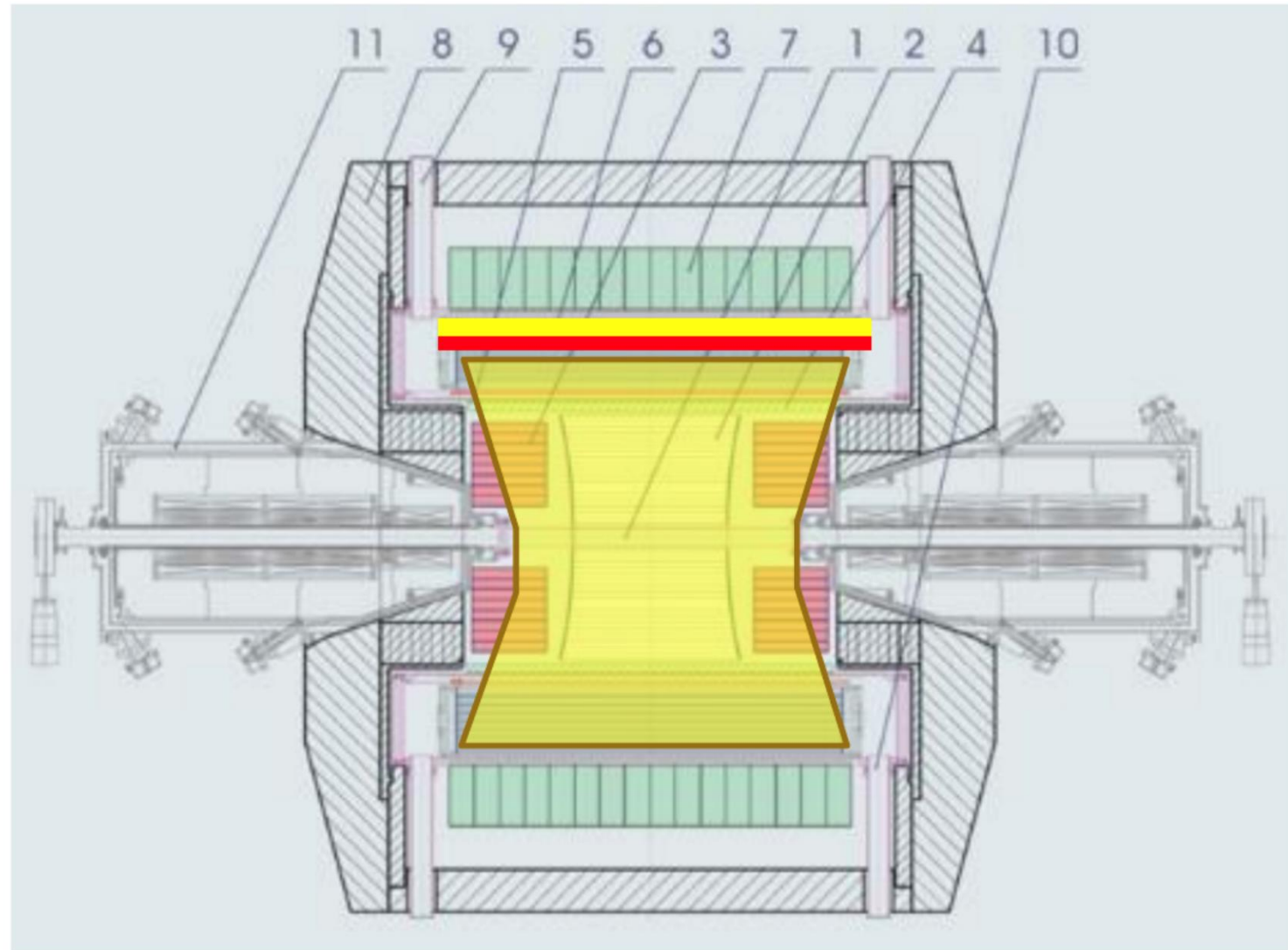
CMD-3 planned upgrades:

- new larger drift chamber with improved $\Delta p/p$ for momentum-based $e/\mu/\pi$ separation
- new Z-chamber at outer radius for precise Θ measurement
- new silicon strip detector at inner radius for precise Θ measurement
- upgrade of electronics
- new superconducting magnet

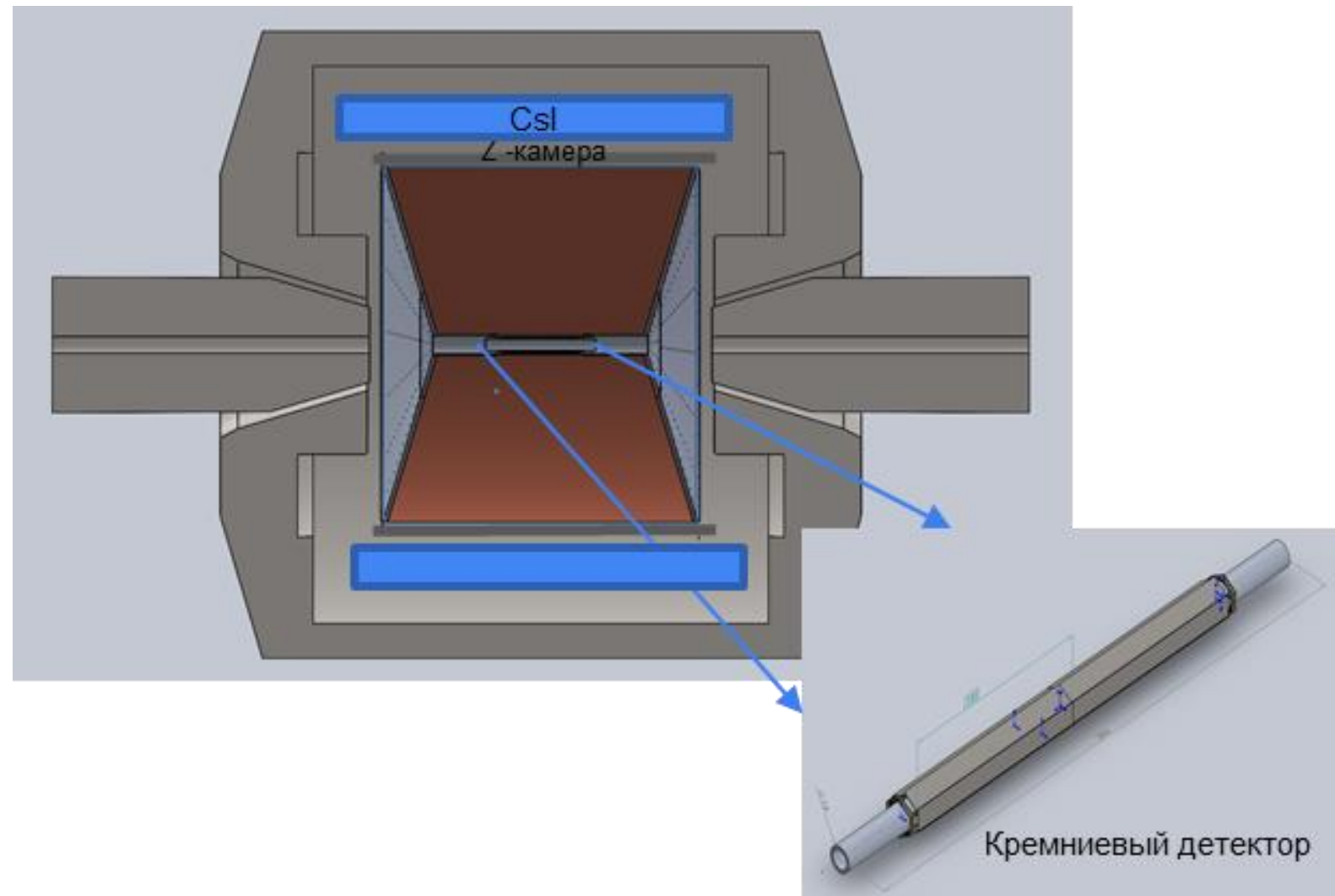
Now working on subsystems design/prototyping

Will stop VEPP-2000 data taking $\sim 1-2$ years before subsystems are ready for installation

CMD-4 vs CMD-3 conceptual view



CMD-4 conceptual view



Si strip detector

Summary

- The CMD-3 collected over 1.1 1/fb of data
- Several new results were presented
- Many more analysis are in progress, including amplitude analyses for 3π , 4π , 5π
- There are plans for major detector upgrade over next few years, aimed at measurement of $\pi^+\pi^-$ cross section at the 0.2% level of precision (ultimately – to match FNAL)