# Data Taking Proposal of tau-QCD group

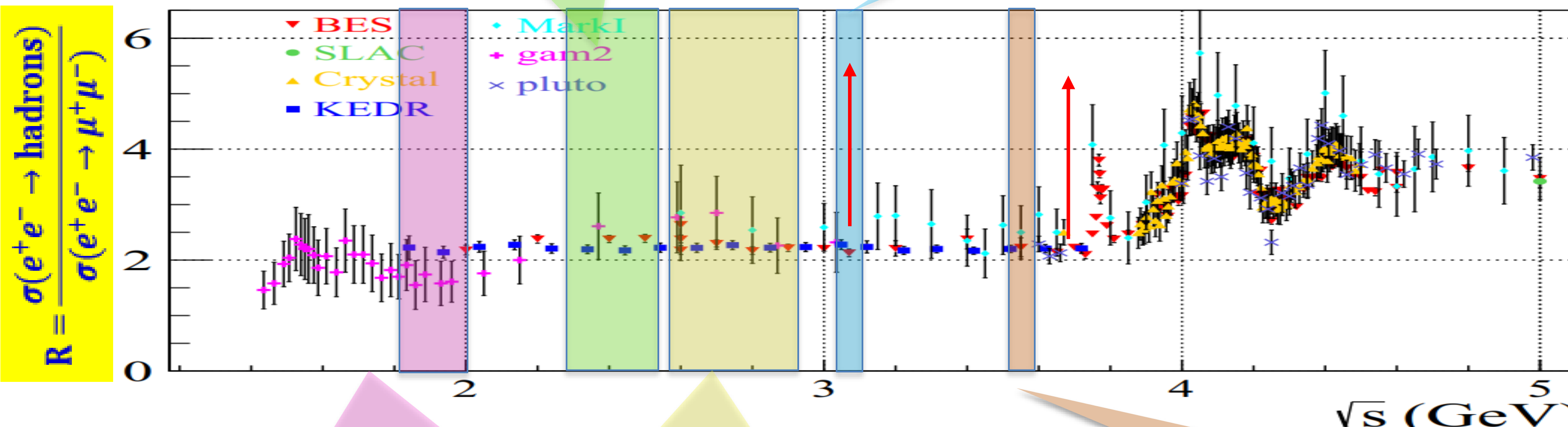
# Summarize of proposal

| Energy | Physics Highlight | Expect lum. | Time | reference |
|---|---|---|---|---|
| 1.8-2.0 GeV | R, nucleon, resonance | 100 $pb^{-1}$ at 23 points | 66 days | Coll. Talk on June 13,2022 |
| 2.26-2.52 GeV | $\Lambda$, Resonance, | 160$pb^{-1}$ at 8 points | 51 days | Coll. Talk on June 13,2022 |
| 2.56-2.88 GeV | Exotic states | 180$pb^{-1}$ at 9 points | 37 days | Coll. Talk on June 13,2022 |
| 2.5 GeV | Hyperon | 100 $pb^{-1}$ | 26 days | White paper |
| $J/\psi$ scan | Phase | 1000 $pb^{-1}$ at several points | 150 days | White paper |
| $\chi_{c2}$ scan | Two-photon production | 800 $pb^{-1}$ at 3 points | 26 days | Riccardo's talk today |

# Physics Interests

Partner of phi(2175)
LamLam threshold
Structure in phiKK, phipipi
Exclusive processes

Phase in Jpsi scan
J/psi->pipi



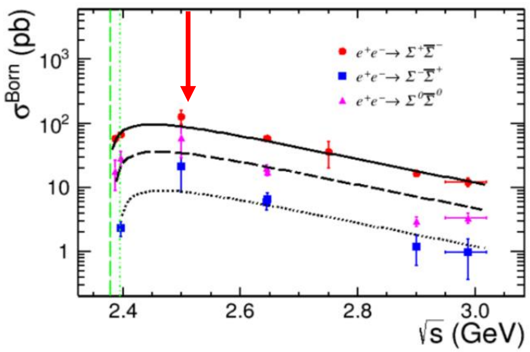

R value, Nucleon FFs at threshold
3(pi+pi-),kkpipi: sharp drop at NN thr. Rho(1910), Phi(1D)

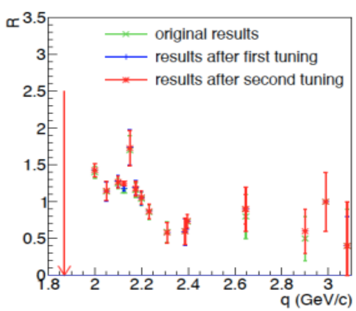
sssbarsbar candidate:
phiKK, omega3pi
Polarization of hyperons:
Lambda, Sigma, Xi

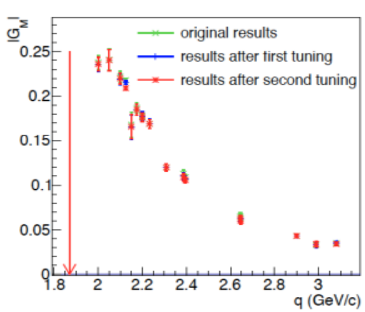
$e^+e^-$ -> chic2
Two-photon production

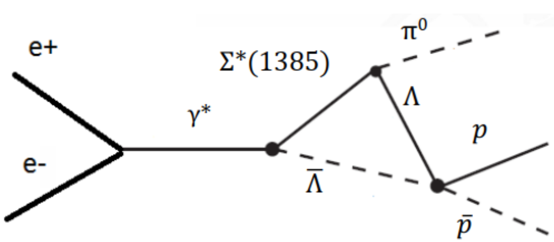
Proposal of chic2 scan has been introduced by Riccardo

# Data taking proposal from Uppsala group: 2.512 GeV, 100 $pb^{-1}$: Hyperon Form Factor



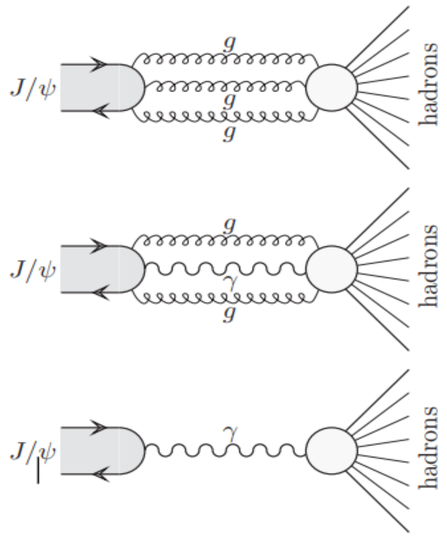



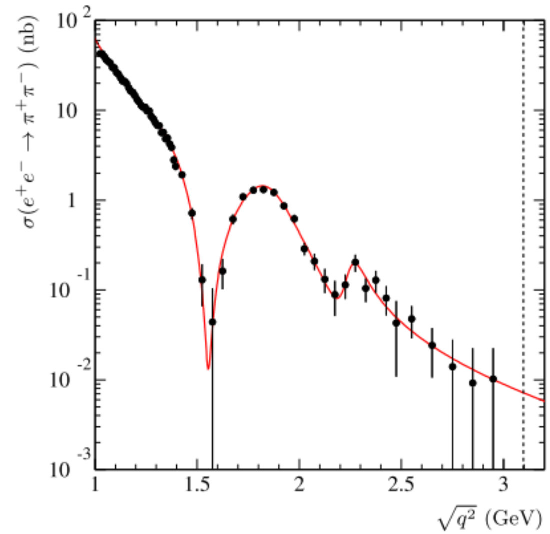




- Complete measurement of hyperon EMFFs
  - Around 2.5 GeV optimal for $\Sigma$
  - 380 $\Lambda\bar{\Sigma}$, 180 $\Sigma^0\bar{\Sigma}^0$, 620 $\Sigma^+\bar{\Sigma}^-$
  - Test diquark model
- Nucleon EMFFs
  - Fills the energy "gap" in the distribution
- Landau singularity
  - Pentaquark interpreted by threshold effect of $\chi_{c1}p$
  - Search for strange counterpart

See detailed physics impact in:
https://indico.ihep.ac.cn/event/6113/session/21/contribution/68/material/slides/0.pdf

# Data taking proposal from Italy group: J/psi scan, 1500 pb$^{-1}$: Relative phase in vector charmonium decays




- An intriguing situation has been found in $J/\psi \to \pi^+\pi^-$, where the EM amplitude is not sufficient to explain partial width of $J/\psi \to \pi^+\pi^-$
- Possible amplitude of two gluons and one virtual photon could exist, that can be determined from relative phase measurement.

**Data taking proposal from USTC-IHEP group:**

**1.8-2.0 GeV, 23 points, 100 $pb^{-1}$ , 66 days**

See detailed physics impact in:
https://indico.ihep.ac.cn/event/16632/session/1/contribution/51/material/slides/0.pdf

# Unique

- Extend the lower limit of energy region by 200 MeV, will be a new record for BESIII
- Able to cover all the baryon SU(3) octet ground states production thresholds
- A transition region where exclusive R and inclusive R can applied
- Existence of excited vector resonances

# Impact of the Energy Region

- A "mysteries" energy region:
  - "dip" structure around 1.9 GeV
  - Threshold enhancement of nucleon EMFFs
  - Excited vector resonance, e.g. $\rho(1900)$
  - Inclusive hadronic measurement
- Wide theoretical discussions
  - Below-threshold $N\bar{N}$ resonance
  - Strong interaction in virtual $N\bar{N}$ production

Proposal

| Ecm (MeV) | Nobs | σ (pb) | eff. | Lum. (/pb) | time (hr) |
|---|---|---|---|---|---|
| 1800 | 0 | 0 | 0 | 3.85 | 77.6 |
| 1820 | 0 | 0 | 0 | 3.85 | 74.3 |
| 1840 | 0 | 0 | 0 | 3.85 | 71.1 |
| 1860 | 0 | 0 | 0 | 3.85 | 68.1 |
| 1870 | 0 | 0 | 0 | 3.85 | 66.6 |
| 1872 | 0 | 0 | 0 | 3.85 | 66.3 |
| 1874 | 0 | 0 | 0 | 3.85 | 66.1 |
| 1876 | 0 | 0 | 0 | 3.85 | 65.8 |
| 1877 | 1000 | 800 | 32.4 | 3.85 | 65.6 |
| 1878 | 1000 | 800 | 32.4 | 3.85 | 65.5 |
| 1880 | 1000 | 800 | 33.3 | 3.75 | 63.6 |
| 1882 | 1000 | 800 | 34.8 | 3.59 | 60.5 |
| 1884 | 1000 | 800 | 36.3 | 3.44 | 57.8 |
| 1886 | 1000 | 800 | 35.7 | 3.5 | 58.5 |
| 1888 | 1000 | 800 | 36.2 | 3.45 | 57.4 |
| 1890 | 1000 | 800 | 36.7 | 3.41 | 56.6 |
| 1900 | 1000 | 800 | 34.7 | 3.6 | 58.5 |
| 1910 | 1000 | 800 | 24.2 | 5.15 | 82 |
| 1920 | 1000 | 800 | 8.2 | 15.2 | 235.9 |
| 1940 | 1000 | 800 | 28.7 | 4.35 | 65.1 |
| 1960 | 1000 | 800 | 43.4 | 2.87 | 41.3 |
| 1980 | 1000 | 800 | 51.1 | 2.44 | 33.6 |
| 2000 | 1000 | 800 | 55.2 | 2.27 | 30 |

- Involved experiments including: e+e- collider (CMD-3, SND, BaBar, FENICE), photoproduction (E687…), more than **20 physics topics**
- Can BESIII give better results?

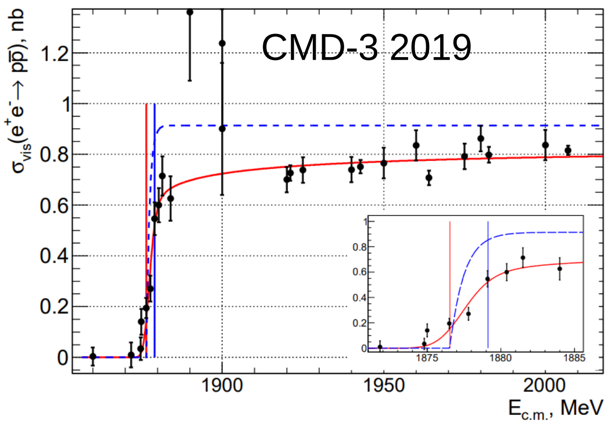
# Competition with other Experiments (I)

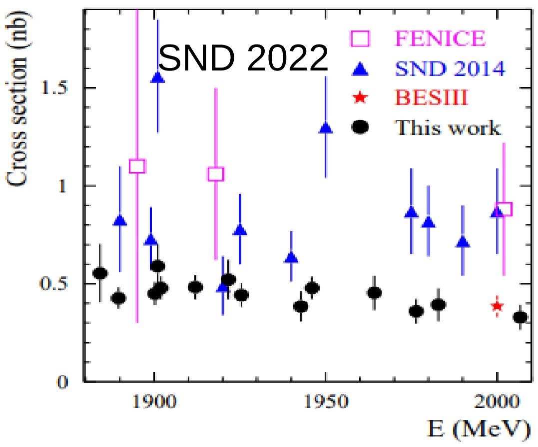
- Dynamics of the "dip" behavior near $N\bar{N}$ threshold, observed in $3(\pi^+\pi^-)$, $2(\pi^+\pi^-\pi^0)$, $2(\pi^+\pi^-)\pi^0$, $K^+K^-\pi^+\pi^-$, $K^+K^-\pi^0\pi^0$, but no in $2(\pi^+\pi^-)$.
  - A threshold effect
  - The rho(1900) resonance

| Parameters | BESIII scan | Other Experiment |
|---|---|---|
| Energy resolution | 0.5 MeV | 0.95 MeV (CMD-3) |
| Inte. Lum. (1.8-2.0 GeV) | 100 $pb^{-1}$ | BESIII(20$fb^{-1}$): 62.43 $pb^{-1}$<br>BelleII(50$ab^{-1}$):16.93 $fb^{-1}$ |
| $3(\pi^+\pi^-)$ | 33000 (30%) | 10155 (<20%) (CMD-3 2019) |
| $2(\pi^+\pi^-\pi^0)$ | 62000 (15%) | 35499 (from 1.4-4.0GeV)<br>Babar2006 |
| $K^+K^-\pi^+\pi^-$ | 135120 (35%)<br>PWA can be applied | 19500 (CMD-3 2019) |

# Competition with other Experiments (II)

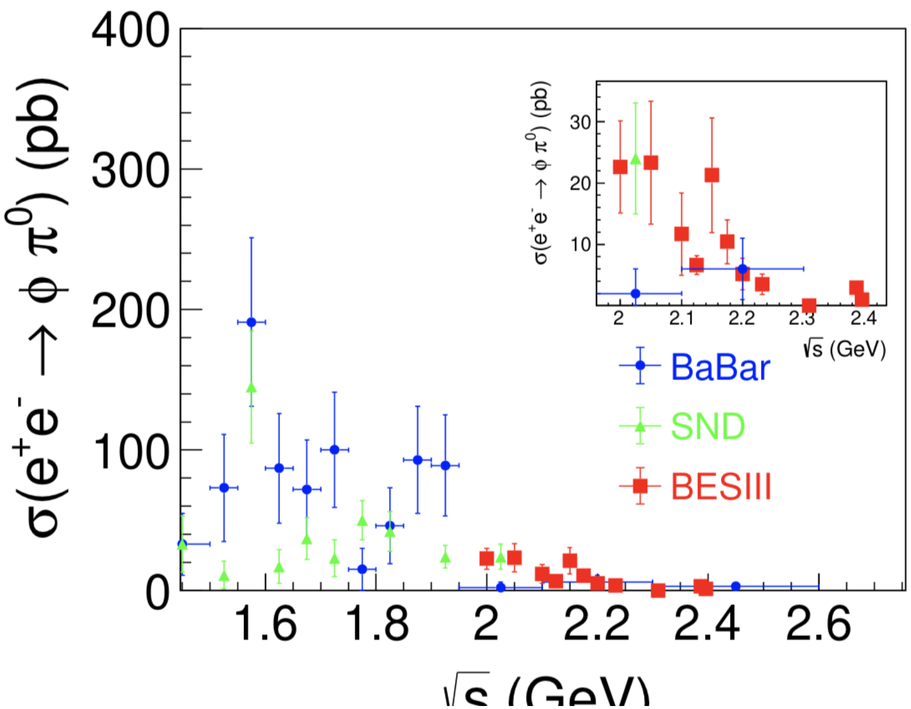
- Abnormal structure of nucleon form factor near threshold
- Precise result from CMD-3/Babar and SND achieved
- Advantage of BESIII:
  - Better energy resolution
  - Coherent analysis of $p\bar{p}$ and $n\bar{n}$



# Competition with other Experiments (III)

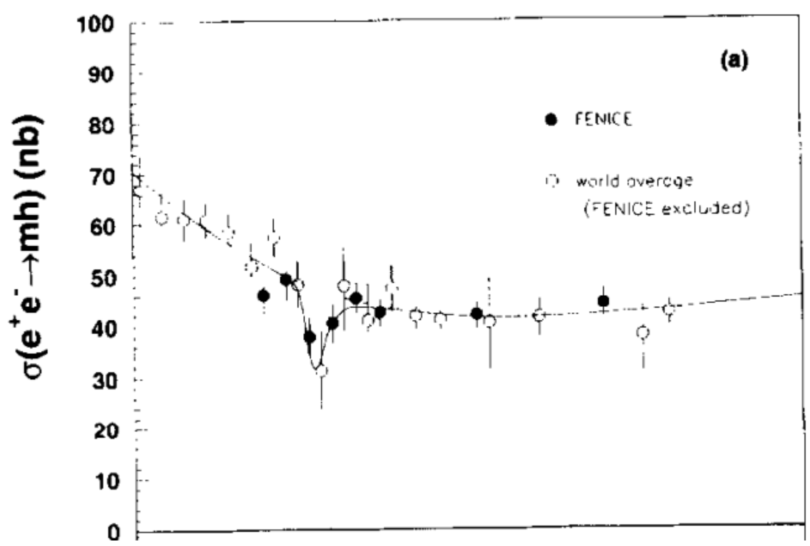
- Rich resonances in 1.8-2.0 GeV
  - A narrow structure in $e^+e^- \to \phi\pi^0$ , indicated by $\rho(1900)$




| $\phi\pi^0$ | BESIII | SND |
| --- | --- | --- |
| Detection Efficiency | 25% | 5% |
| Signal No. | ~3000 | ~20 |

# Competition with other Experiments (IV)

- $e^+e^-$ annihilation into hadrons
  - Inclusive data and pQCD calculations agree within uncertainties, disagree with exclusive sum, important for muon g-2
  - A narrow structure observed near $N\bar{N}$ threshold by FENICE




| | BESIII | Fenice |
|---|---|---|
| No. signal | >1e06 | 10000 |
| Systematic unc. | <3% | 6% |

# Competition with other Experiments

| | BESIII scan (1.8-2.0 GeV) | BESIII ISR (20fb$^{-1}$ $\psi''$) | CMD-3 | Belle II (50 ab$^{-1}$) |
|---|---|---|---|---|
| Energy resolution | ★ ★ ★ | ★ | ★ ★ | ★ |
| Efficiency | ★ ★ ★ | ★ | ★ ★ | ★ |
| Neutral reconstruction | ★ ★ ★ | ★ ★ | ★ ★ | ★ |
| Purity | ★ ★ ★ | ★ | ★ ★ ★ | ★ |
| Statistics | ★ ★ ☆ | ★ | ★ ★ | ★ ★ ★ |
| Systematic uncertainty | ★ ★ ★ | ★ | ★ ★ | ★ |

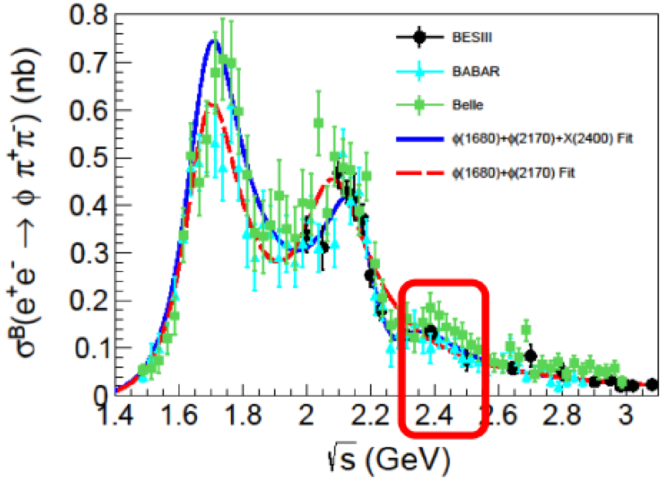
**Data taking proposal from USTC group:**

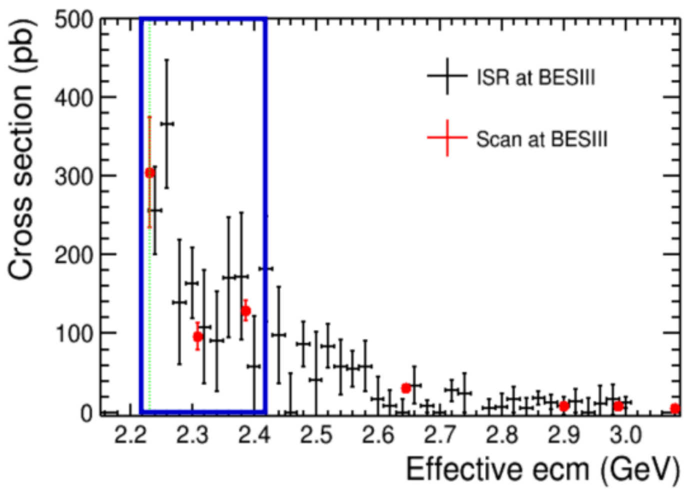
**2.26-2.52 GeV, 8 points, 160 $pb^{-1}$, 51 days**

**2.56-2.88 GeV, 9 points, 180 $pb^{-1}$, 37 days**

See detailed physics impact in:
https://indico.ihep.ac.cn/event/16632/session/1/contribution/51/material/slides/0.pdf

# Around $\Lambda\bar{\Lambda}/\Sigma\bar{\Sigma}$ thresholds



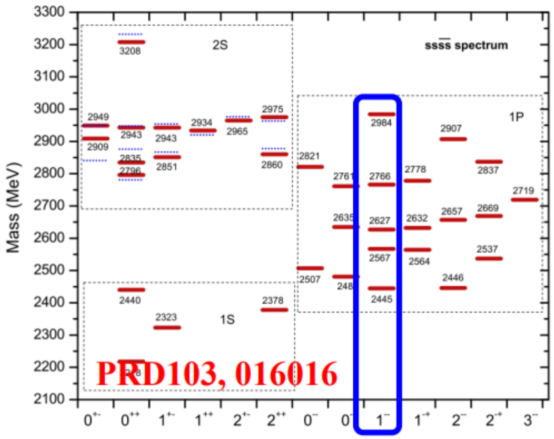

- Structure around $\Lambda\bar{\Lambda}$ threshold observed in $\phi KK$,$\phi\pi\pi$
  - Possible partner of $\phi(2170)$,
  - Threshold effect

- **Data taking @ [2.26-2.52]GeV: 8 points, 51 days in total**

| √s (GeV) | 2.26 | 2.34 | 2.42 | 2.44 | 2.46 | 2.48 | 2.50 | 2.52 |
|---|---|---|---|---|---|---|---|---|
| Int. lumi. | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Time(day) | 8.4 | 7.3 | 6.4 | 6.2 | 6.0 | 5.8 | 5.6 | 5.5 |

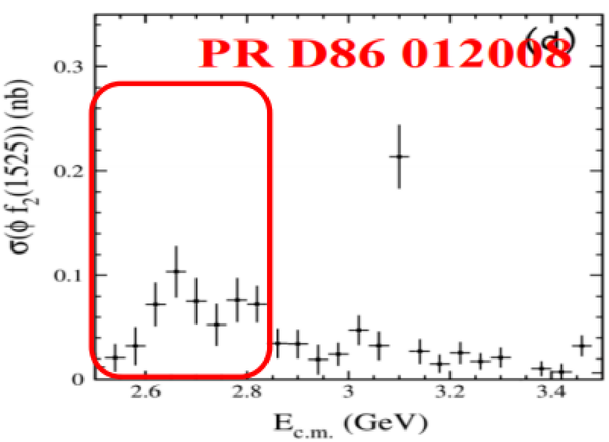
  - 3500 signal events for $\phi KK$ and $\phi\pi\pi$ each
  - $\Lambda\bar{\Lambda}$ line-shape and complete EMFFs
  - Reveal the structure at 2.5 GeV for $\Sigma\bar{\Sigma}$

# Around $\Xi\bar{\Xi}$ threshold



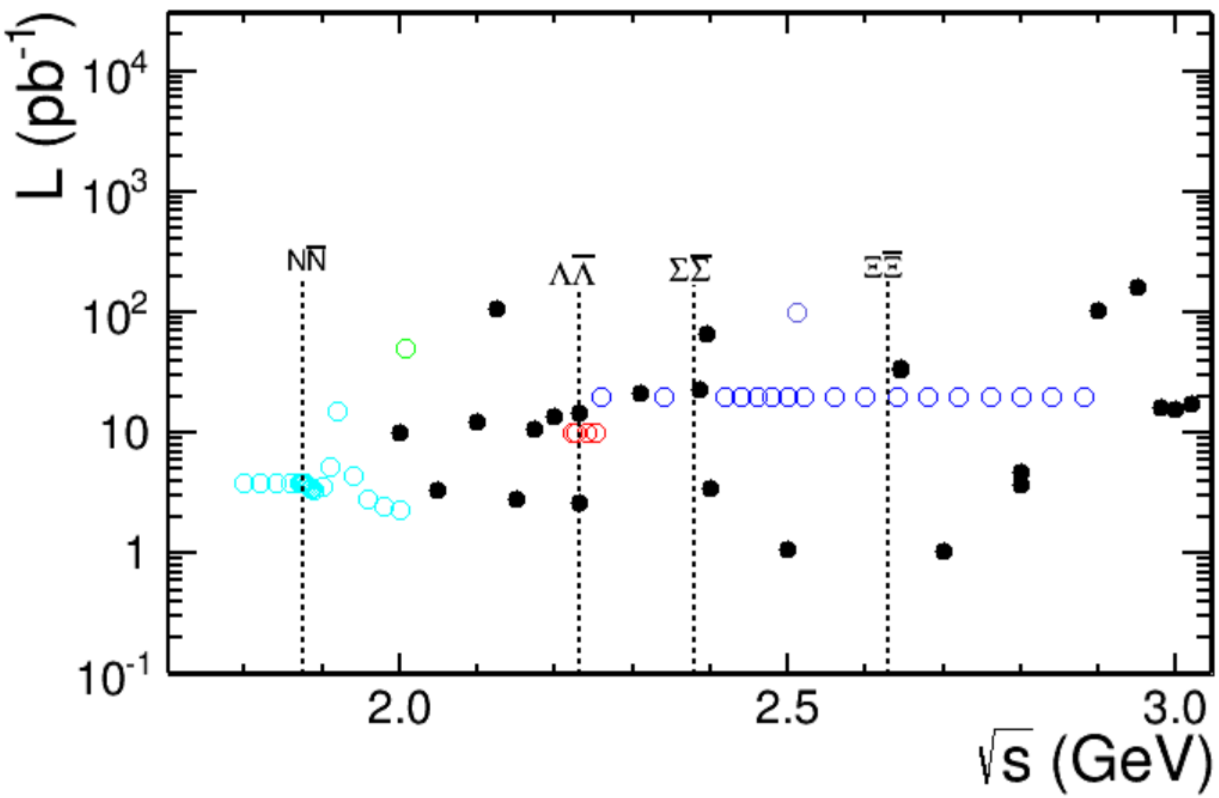

- Theoretical prediction of a $s\bar{s}s\bar{s}$ state
  - Counterpart of $c\bar{c}c\bar{c}$ is observed above 6.0 GeV
- Hints from $\phi KK$
  - Dominant with $\phi f_2(1525)$, with four strange quarks
  - 2200 $\phi f_2(1525)$ signal foreseen at BESIII

$ss\bar{s}\bar{s}$ Candidate




- **Data taking @ [2.56-2.88]GeV**
- **9 points, 37 days in total**

| $\sqrt{s}$ (GeV) | 2.56 | 2.60 | 2.64 | 2.68 | 2.72 |
|---|---|---|---|---|---|
| Int. lumi. | 20 | 20 | 20 | 20 | 20 |
| Time(day) | 5.1 | 4.8 | 4.5 | 4.3 | 4.0 |
| $\sqrt{s}$ (GeV) | 2.76 | 2.80 | 2.84 | 2.88 | |
| Int. lumi. | 20 | 20 | 20 | 20 | |
| Time(day) | 3.8 | 3.6 | 3.4 | 3.2 | |




- With Better resolution, high detection efficiency, low background, BESIII is an ideal place to study the interesting physics (resonance, threshold effects, R) in 1.8-2.8 GeV with scan method.

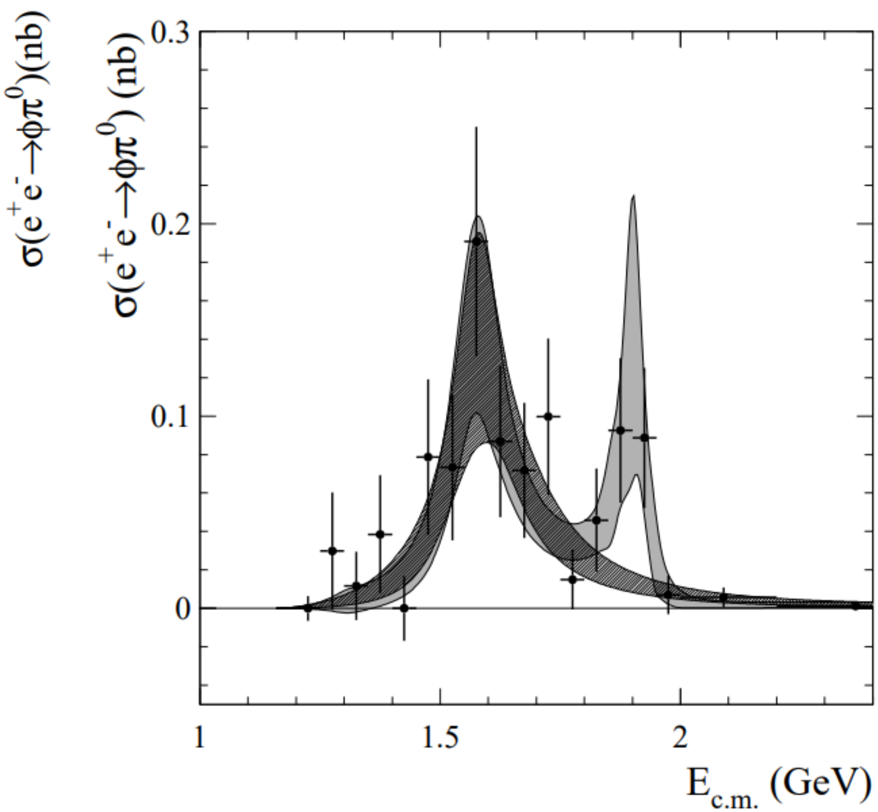
# THANK YOU

# BACKUP

# Reference 209

TABLE XII: Measurement of the $e^+e^- \to \phi\pi^0$ cross section as a function of $E_{c.m.}$. Errors are statistical only.

| $E_{c.m.}$ (GeV) | $\sigma$ (nb) | $E_{c.m.}$ (GeV) | $\sigma$ (nb) | $E_{c.m.}$ (GeV) | $\sigma$ (nb) | $E_{c.m.}$ (GeV) | $\sigma$ (nb) |
|---|---|---|---|---|---|---|---|
| 1.20−1.30 | 0.014 ± 0.016 | 1.55−1.60 | 0.191 ± 0.060 | 1.75−1.80 | 0.015 ± 0.015 | 1.95−2.10 | 0.002 ± 0.004 |
| 1.30−1.40 | 0.025 ± 0.018 | 1.60−1.65 | 0.087 ± 0.039 | 1.80−1.85 | 0.046 ± 0.027 | 2.10−2.30 | 0.006 ± 0.005 |
| 1.40−1.50 | 0.033 ± 0.022 | 1.65−1.70 | 0.072 ± 0.035 | 1.85−1.90 | 0.093 ± 0.038 | 2.30−2.60 | 0.002 ± 0.002 |
| 1.50−1.55 | 0.073 ± 0.038 | 1.70−1.75 | 0.100 ± 0.041 | 1.90−1.95 | 0.089 ± 0.036 | | |




The cross section parametrization used to fit the data leading to the final state $f$, $e^+e^- \to f$, at $s = E^2_{c.m.}$ is

$$\sigma_f(s) = 12\pi \mathcal{P}_f(s) \Bigg| A_f^{n.r.}(s) + \\ + \sum_R \sqrt{\mathcal{B}_f^R \Gamma_{ee}^R} \frac{\sqrt{\Gamma_R/\mathcal{P}_f(M_R^2)}e^{i\Psi_R}}{M_R^2 - s - i\sqrt{s}\Gamma_R(s)} \Bigg|^2, \quad (11)$$

where $\mathcal{P}_f(s)$ is the phase space of the $f$ final state, $A_f^{n.r.}(s)$ describes the non-resonant background, mainly due to the tails of resonances below threshold, and the sum runs over all the vector resonances, with mass $M_R$, width $\Gamma_R$ and relative phase $\Psi_R$, assumed to contribute to the cross section. All of the final states analyzed contain a vector and a pseudoscalar meson. The phase space for $f = VP$ has the form:

$$\mathcal{P}_{VP}(s) = \left[ \frac{(s + M_V^2 - M_P^2)^2 - 4M_V^2 s}{s} \right]^{\frac{3}{2}}. \quad (12)$$

where $\mathcal{P}_{4\pi}(s)$ is the four-pion phase space defined in Eq. 19, and $\mathcal{B}_{4\pi}^{\rho''}$ is the branching fraction for $\rho'' \to 4\pi$.

The results of the fit with only the $\rho''$ are reported in the first column of the Table XVI.

In the second case, where the $\rho(1900)$ is also included, a two step procedure is used to determine the phases of the two quasi-real amplitudes. We find $(\Psi_{\rho''}, \Psi_{\rho(1900)}) = (0, \pi)$ to be the best combination. With these phases we get the results reported in the second and third columns of the Table XVI.

The results of the two fits are shown in Fig. 40, superimposed on the cross section data.

A slightly better $\chi^2$ is obtained by adding this extra resonance. We can not however exclude that the observed accumulation of events at $E_{\rm c.m.} \approx 1.9$ GeV is produced by a statistical fluctuation. In fact, we observe 18 events to be compared to an expectation of 8 events, taking into account both the background and the tail of the $\rho''$, and this translates in a Poisson probability of $2 \times 10^{-3}$.

Mass, width, and quantum numbers $[I^G(J^{PC}) = 1^+(1^{--})]$ obtained for the $\rho(1900)$ are compatible with those of the so-called "dip" observed in other channels, primarily multi-pion final states [27].

TABLE XVI: Parameters obtained for the $\phi\pi^0$ cross section. First column: with the only $\rho''$ resonance, second and third columns: including also the $\rho(1900)$. The normalized $\chi^2$ and corresponding C.L. are reported in each case.

| $(\frac{\chi^2}{\rm n.d.f.}$,C.L.) | $(\frac{14.36}{16-5}, 0.31)$ | $(\frac{7.37}{16-8}, 0.50)$ | |
|---|---|---|---|
| $R$ | $\rho''$ | $\rho''$ | $\rho(1900)$ |
| $\Gamma_{ee}^R \mathcal{B}_{\phi\pi^0}^R$( eV) | 4.4±1.0 | 3.5±0.9 | 2.0±0.6 |
| $(1-\mathcal{B}_{4\pi}^R)$ | 0.67±0.43 | 0.44±0.49 | - |
| $M_R$( MeV) | 1593±32 | 1570±36 | 1909±17 |
| $\Gamma_R$( MeV) | 203±97 | 144±75 | 48±17 |
| $\Psi_R$(rad) | 0 | 0 | $\pi$ |
| $\sigma_{\phi\pi^0}^{\rm bkg}(M^2_{\rho(1900)})$(nb) | $(0.4\pm0.2)\times10^{-3}$ | $(0.5\pm1.5)\times10^{-3}$ | |

# Cover a wide Program

- Abnormal structure of nucleon form factor near threshold
- Dynamics of the “dip” behavior near $N\bar{N}$ threshold, observed in 3 $(\pi^+\pi^-)$, $2(\pi^+\pi^-\pi^0)$, 2 $(\pi^+\pi^-)\pi^0$, $K^+K^-\pi^+\pi^-$, $K^+K^-\pi^0\pi^0$, but no in 2$(\pi^+\pi^-)$.
  - A threshold effect
  - The rho(1900) resonance
- Rich resonances in 1.8-2.0 GeV
  - A narrow structure in $e^+e^- \rightarrow \phi\pi^0$
- $e^+e^-$ annihilation into hadrons
  - Inclusive data and pQCD calculations agree within uncertainties, disagree with exclusive sum => important for muon g-2
  - A narrow structure observed near $N\bar{N}$ threshold by FENICE