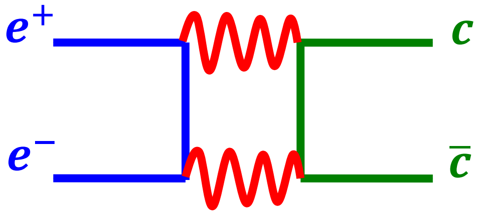
Data taking proposal: Search for $e^+e^- \to \chi_{c2}$

R. Aliberti (JGU Mainz U.)
A. Denig (JGU Mainz U.)
Y. Guo (Fudan U.)
T. Liu (Fudan U.)
Ch. Redmer (JGU Mainz U.)

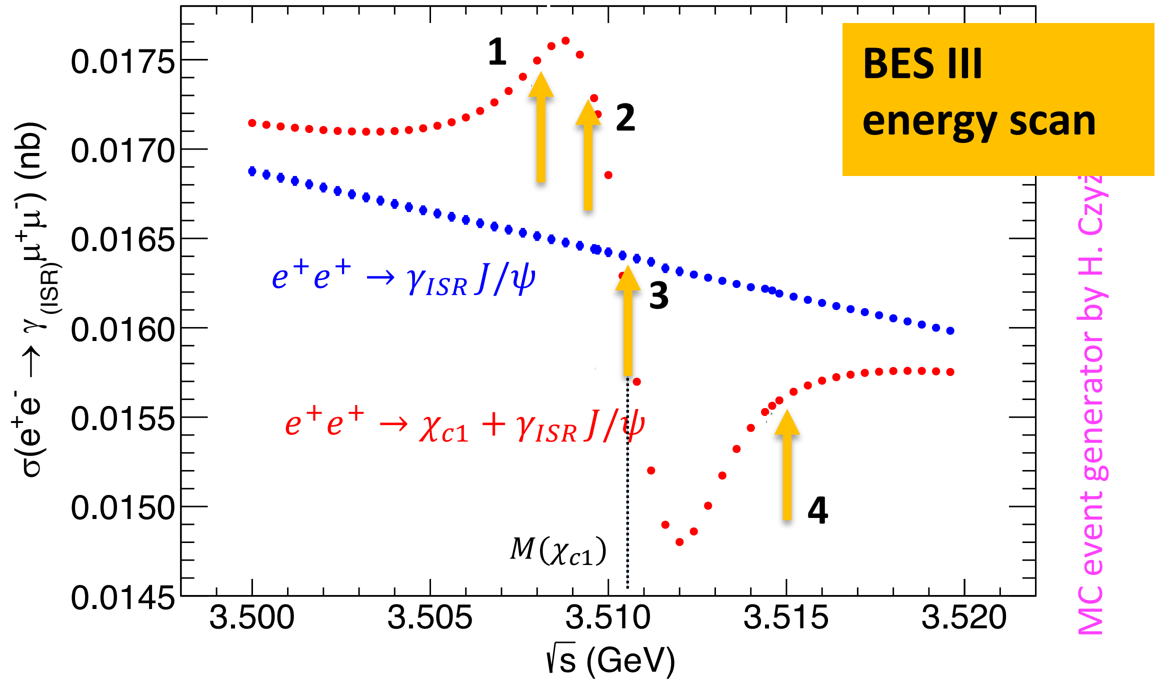
What we already have: $e^+e^- \to \chi_{c1}$



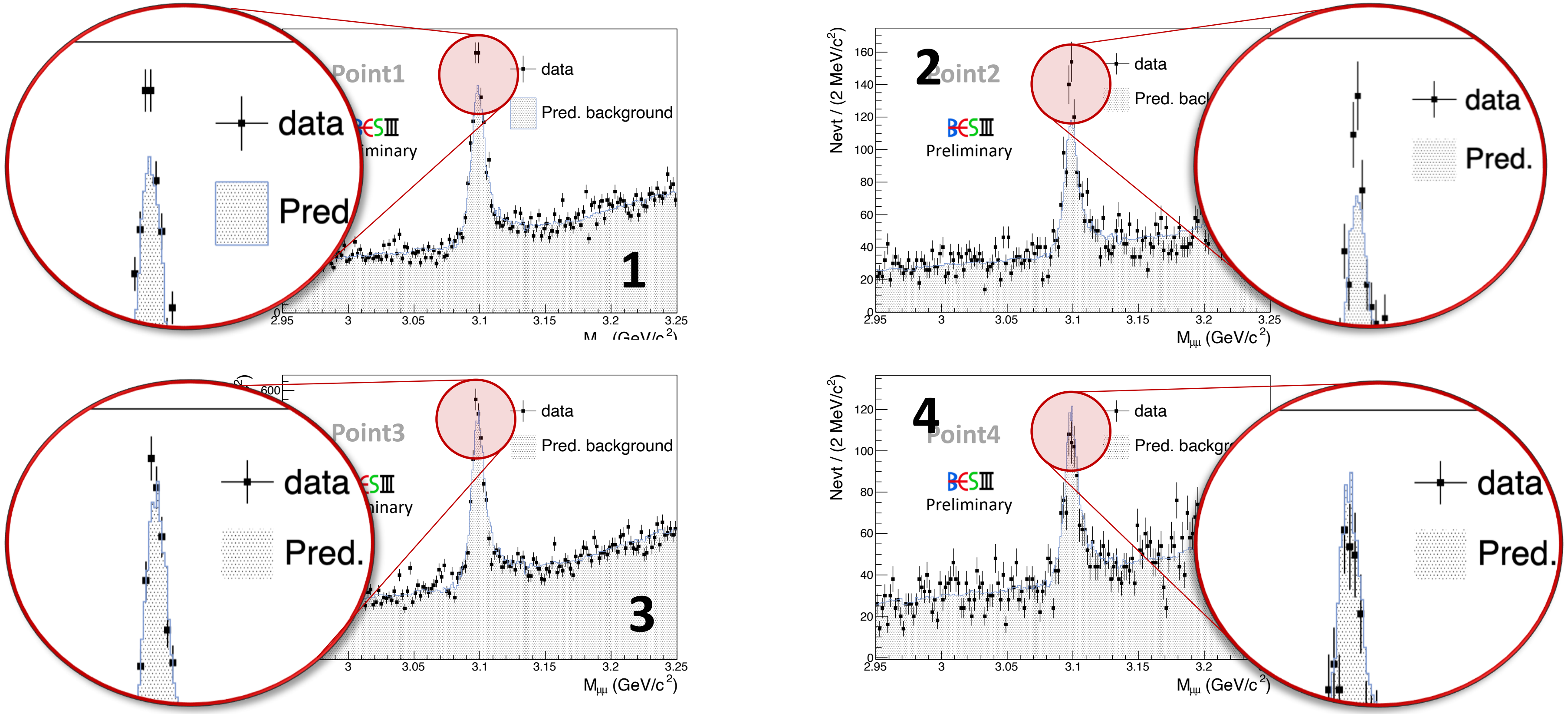
$e^+e^- \to \chi_{c1}$ ($J^{PC}=1^{++}$)
M=3.51 GeV/c²

- Unitarity limit: $\Gamma_{ee} > 0.044$ eV J. Laplan, J. H. Kühn, PLB78, 252 (1978)
- Vector Dominance Model: $\Gamma_{ee} = 0.46$ eV; OR $\Gamma_{ee} \sim 0.1$ eV A. Denig, F. K. Guo, C. Hanhart, A. V. Nefediev, PLB736, 221 (2014)
- Non-relativistic QCD: $\Gamma_{ee} \sim 0.1$ eV N. Kivel, M. Vanderhaeghen, JHEP02, 032 (2016)
- Latest prediction: $\Gamma_{ee} = 0.43$ eV; interference with background process! H. Czyż, J. H. Kühn, S. Tracz, PRD94, 034033 (2016)

- Search for $\chi_{c1} \to \gamma\, J/\psi \to \gamma\, \mu^+\mu^-$
- Background from $e^+e^- \to \gamma_{\rm ISR}\, J/\psi \to \gamma_{\rm ISR}\, \mu^+\mu^-$ (Phokhara)



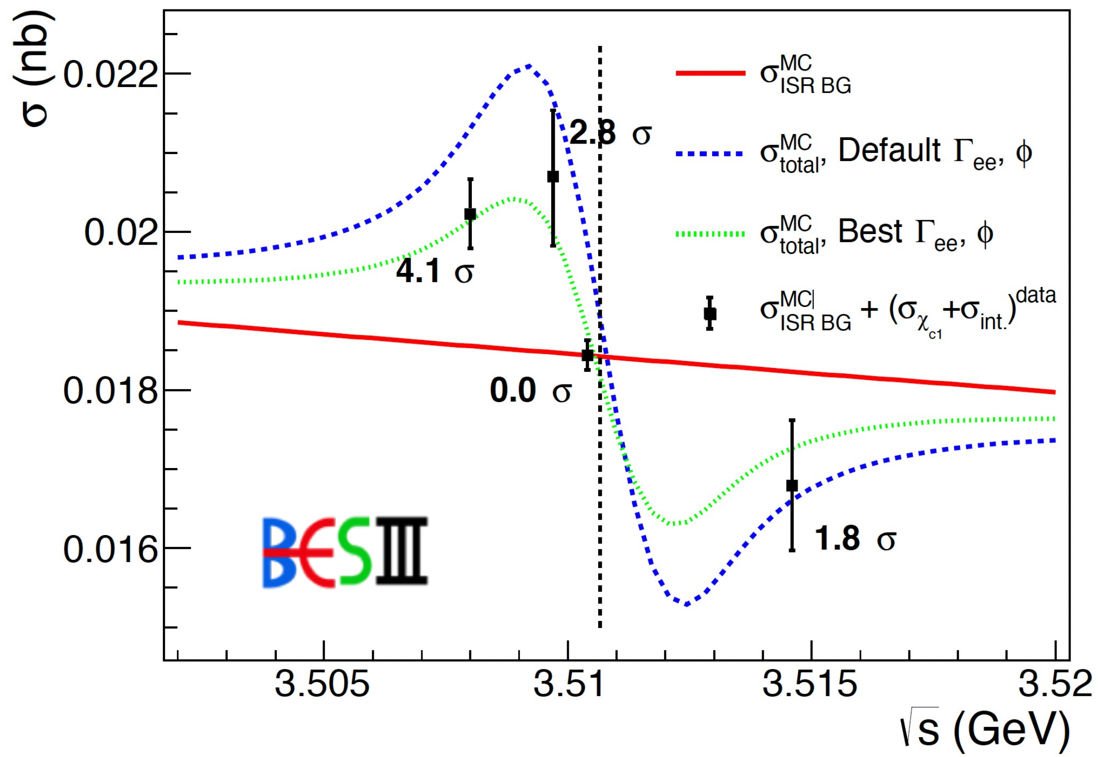
What we already have: $e^+e^- \to \chi_{c1}$



What we already have: $e^+e^- \rightarrow \chi_{c1}$

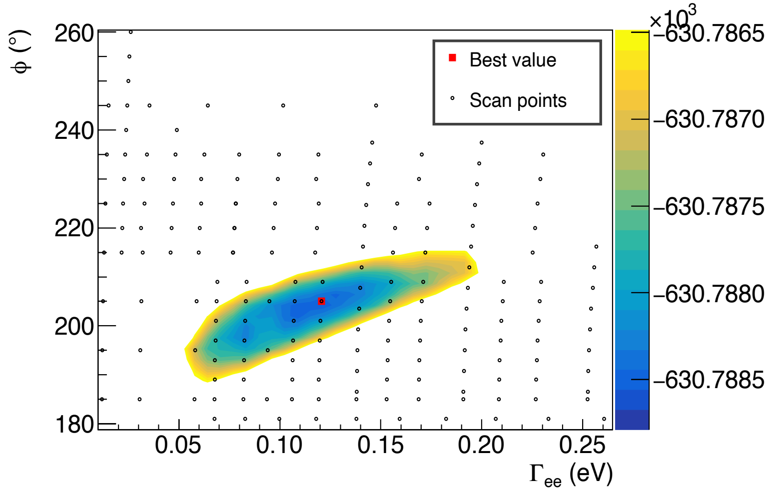
Combination of 4 energy points yields a significance of 5.1σ:

First observation of a non-vector resonance in e^+e^- annihilation!



Common fit to all 4 scan points

$\Gamma_{ee}=0.12^{+0.13}_{-0.08}$ eV, $\phi=205°^{+15.4°}_{-22.4°}$



→ New production mechanism for resonances in e^+e^-(spectroscopy!)

→ Currently working on ISR analysis of $e^+e^- \rightarrow f_1(1285)$

arxiv:2203.13782, submitted to Phys. Rev. Lett., two very positive referee reports → expect to be pubished shortly

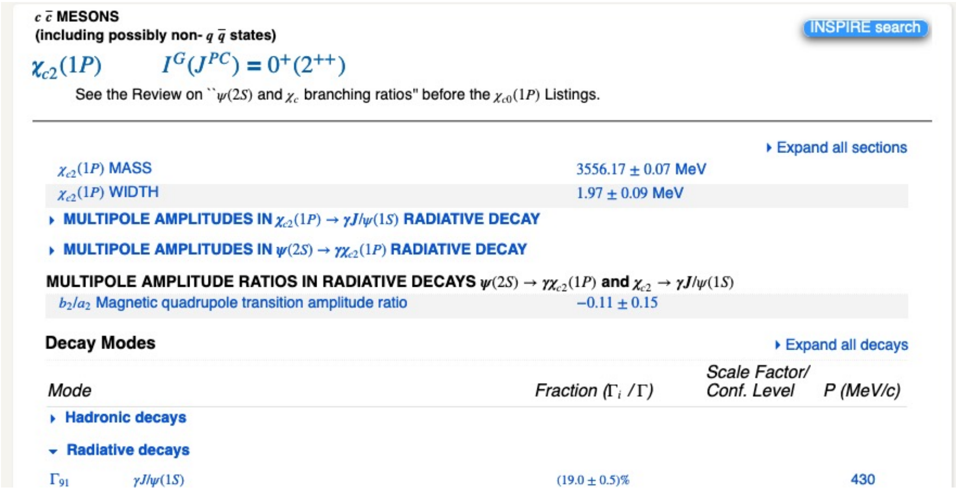
Why embark now on $e^+e^- \to \chi_{c2}$?

- Results on χ_{c1} have been shown at conferences
  → very strong interest from the community, spectroscopy experts, LHC people, ... muon g-2 experts

- New: two-photon production of resonances can be
  related to HLbL-contribution of muon g-2 (see recent workshop of g-2 theory initiative)

- Finally confirm our findings on χ_{c1} with a second charmonium resonance
  → χ_{c2} with $J^{PC}=2^{++}$, i.e. different quantum numbers
  → use same decay mode: radiative decay into J/psi (19% BR)
  → very straight-forward continuation of previous analysis

- Next step after confirmation of χ_{c2} is to apply method for
  XYZ states, e.g. X(3872)
  → determine line shape of resonance and gain information
  on internal nature
  → establish a new approach in hadron spectroscopy at e+e-
  colliders (super-tau-charm colliders)



$c\bar{c}$ MESONS
(including possibly non-$q\bar{q}$ states)

INSPIRE search

$\chi_{c2}(1P)$ $I^G(J^{PC}) = 0^+(2^{++})$

See the Review on "$\psi(2S)$ and χ_c branching ratios" before the $\chi_{c0}(1P)$ Listings.

Expand all sections

$\chi_{c2}(1P)$ MASS 3556.17 ± 0.07 MeV
$\chi_{c2}(1P)$ WIDTH 1.97 ± 0.09 MeV

MULTIPOLE AMPLITUDES IN $\chi_{c2}(1P) \to \gamma J/\psi(1S)$ RADIATIVE DECAY

MULTIPOLE AMPLITUDES IN $\psi(2S) \to \gamma\chi_{c2}(1P)$ RADIATIVE DECAY

MULTIPOLE AMPLITUDE RATIOS IN RADIATIVE DECAYS $\psi(2S) \to \gamma\chi_{c2}(1P)$ and $\chi_{c2} \to \gamma J/\psi(1S)$

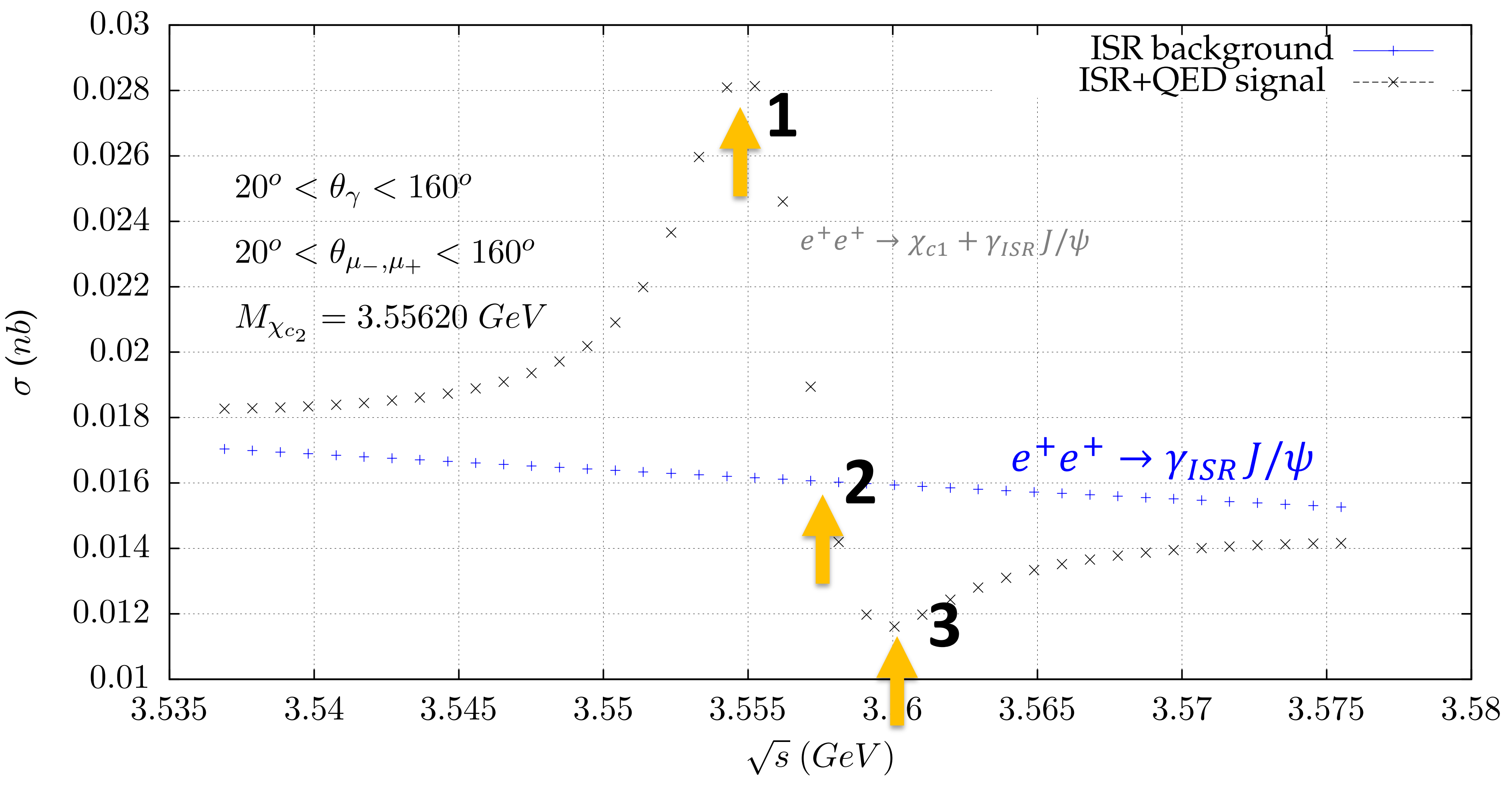
b_2/a_2 Magnetic quadrupole transition amplitude ratio −0.11 ± 0.15

Decay Modes

Expand all decays

	Mode	Fraction (Γ_i/Γ)	Scale Factor/ Conf. Level	P (MeV/c)
Hadronic decays				
Radiative decays				
Γ_{91}	$\gamma J/\psi(1S)$	$(19.0 \pm 0.5)\%$		430

Data taking proposal for $e^+e^- \to \chi_{c2}$



Data taking proposal for $e^+e^- \rightarrow \chi_{c2}$

cms energy / GeV	Int. Luminosity /pb-1	Time* / day
3.554	300	8.5
3.558	200	6
3.560	300	8.5

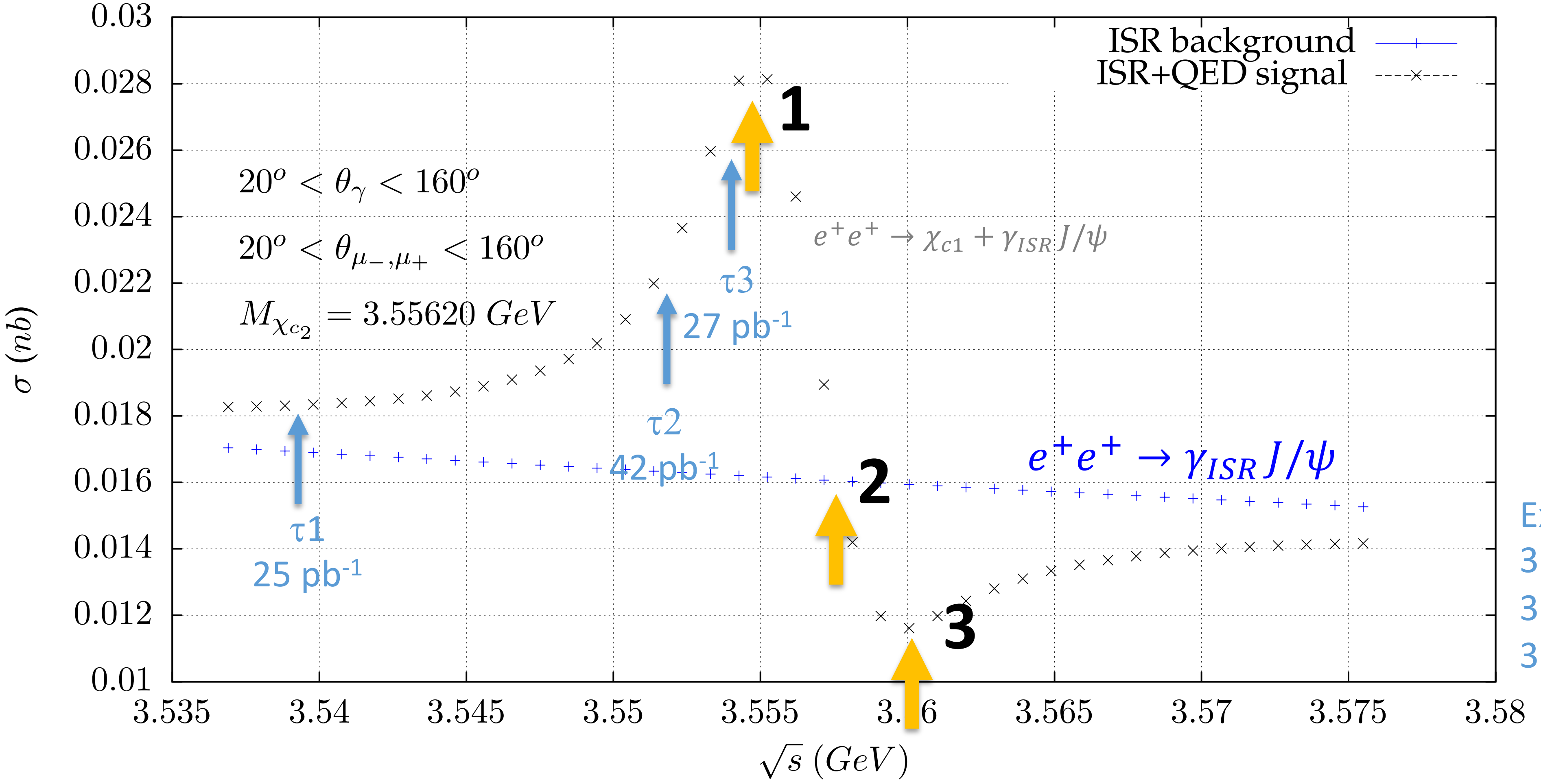
*** assuming an effective and realistic performance of 35 pb^{-1} / day (→ see BEPC-II report Coll. Meeting)**

BEMS needed (assume 1 day per data point --> 3 additional days)

We request 26 days of data taking for the $e^+e^- \rightarrow \chi_{c2}$ scan

3 Data Points: 3.554 GeV, 3.558 GeV, 3.560 GeV

Existing Data Points from tau Scan

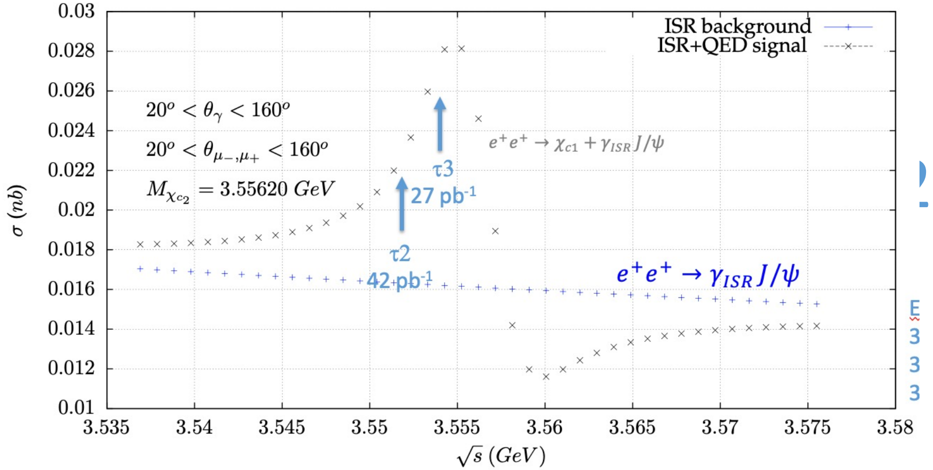


Existing tau scan
3.539 GeV – 25pb-1
3.553 GeV – 42pb-1
3.554 GeV – 27pb-1

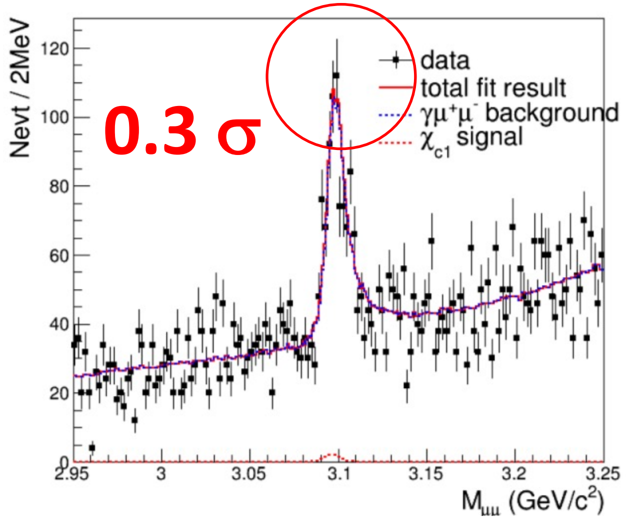
First glimpse into existing tau-scan data

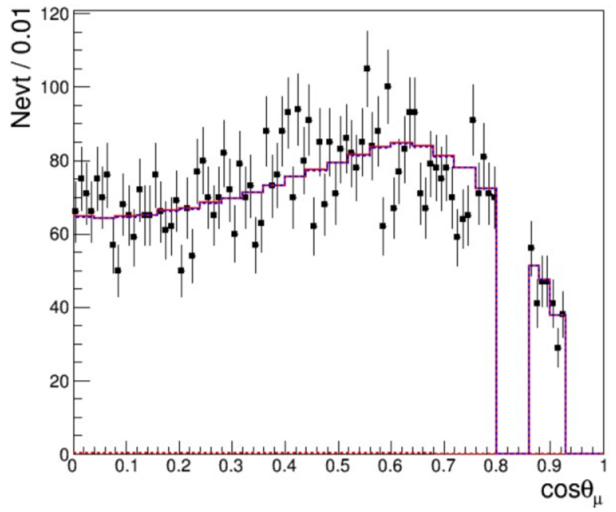
Big thanks to Tong Liu !

Without calibrations and smearing corrections;
no interference taken into acount

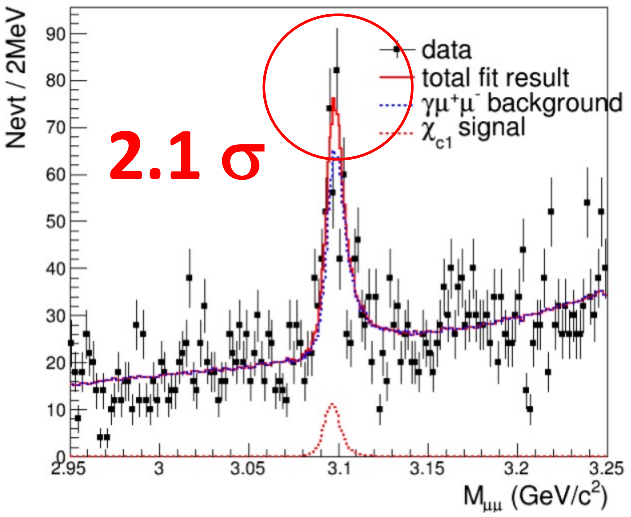


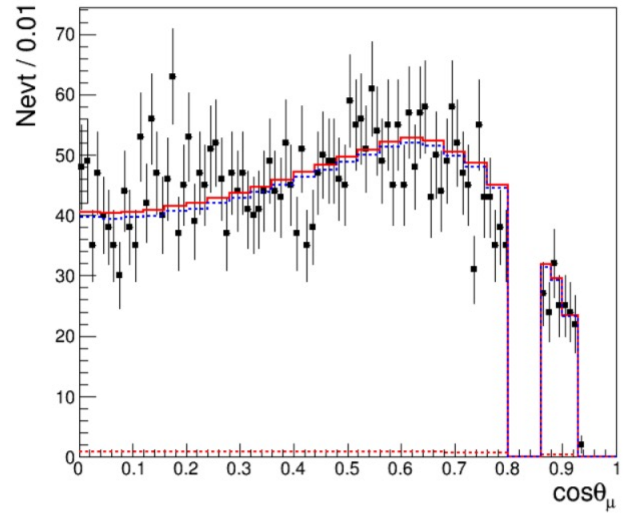
τ2
42 pb^{-1}





τ3
27 pb^{-1}

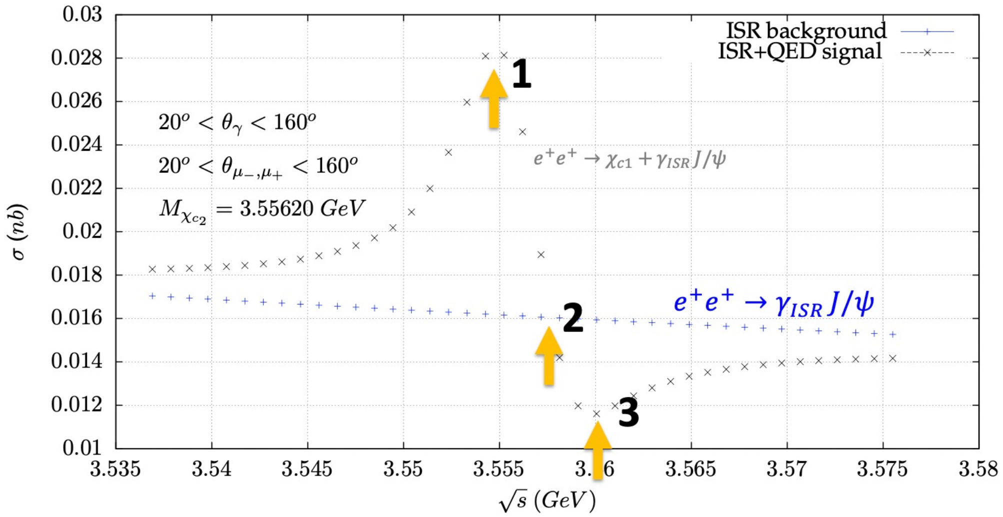




Conclusions

Investment

- Data taking around the chi_c2
- 3 points with in total 800 pb-1
- BEMS system desired
- 26 days of data taking



Harvest

- Establish two-photon production in e+e- physics as a new tool → future e+e- colliders
- Method demonstrated in system with two different quantum numbers
- Recognition by wide community → high-profile publication
- Most relevant for hadronic LbL contribution to muon g-2 → great visibility

New Research Unit on Photon-Photon-Interaction approved → chi_c2 scan proposed!

Photon-photon interactions in the Standard Model and beyond: New research unit at JGU granted DFG funding

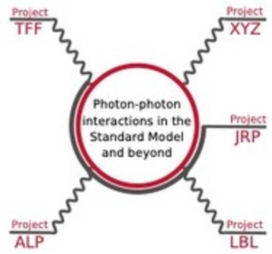
A pure quantum effect as the key to a better understanding of the subatomic world / New research program in Mainz bundles a wide range of expertise

11 April 2022

In classical physics, the superposition of light waves resulting in interference is a well-known phenomenon. An interaction of light rays in the sense of a scattering is, however, classically impossible. Conversely, in the subatomic world, which is described by quantum effects, the quantum particles of light – known as photons – do indeed interact with each other. Moreover, photon-photon interactions play a crucial role in the Standard Model of particle physics. A better understanding of this pure quantum effect is the key to gaining important new insights both within the Standard Model as well as beyond it. This photon-photon interaction is the focus of a new research unit at Johannes Gutenberg University Mainz (JGU). Funding for the research unit has just been approved by the German Research Foundation (DFG); the DFG will initially provide roughly 3.5 million Euros over the next four years. The spokesperson of the research unit is Professor Achim Denig, an experimental physicist and the co-spokesperson is Professor Marc Vanderhaeghen, a theoretical physicist, both of whom work at JGU's Institute of Nuclear Physics.

The light-by-light scattering effect was theoretically predicted by Euler and Heisenberg in 1936, but the effect has only recently been experimentally confirmed at CERN's Large Hadron Collider (LHC). It is still true that photons do not interact directly with each other in the quantum world. The scattering is caused by the exchange of virtual particles which, according to Heisenberg's uncertainty principle, can appear briefly in the vacuum – for example through the interaction with quarks, which are subject to the strong interaction. This so-called "hadronic light-by-light scattering", along with other hadronic effects, provides significant contributions to a theoretical prediction of precision observables within the Standard Model. It is important to consider that a calculation of these effects is complex and therefore usually limited in its accuracy. "The aim of our research unit is to overcome the existing limitations for describing photon-photon interactions. This will have far-reaching consequences for how we perceive subatomic matter and for precision tests of the Standard Model – for example with regard to the anomalous magnetic moment of the muon," points out Professor Achim Denig. "Photon-photon interactions are thus the key to a whole range of discoveries in the field of hadron and particle physics. The study of this interaction could potentially lead to the detection of new particles that are beyond the Standard Model – such as axion-like particles that are considered the most promising candidates for dark

PRISMA+



Ill./©: Institute of Nuclear Physics

The logo of the new research group showing the five subprojects in the shape of a so-called Feynman diagram of photon-photon interactions.

photo/©: Institute for High Energy Physics (IHEP), Beijing

Some of the experimental measurements of the research group will be performed using the BES-III detector in Beijing.