Studies of the relative phase between strong and electromagnetic decay amplitudes of psi(2S)

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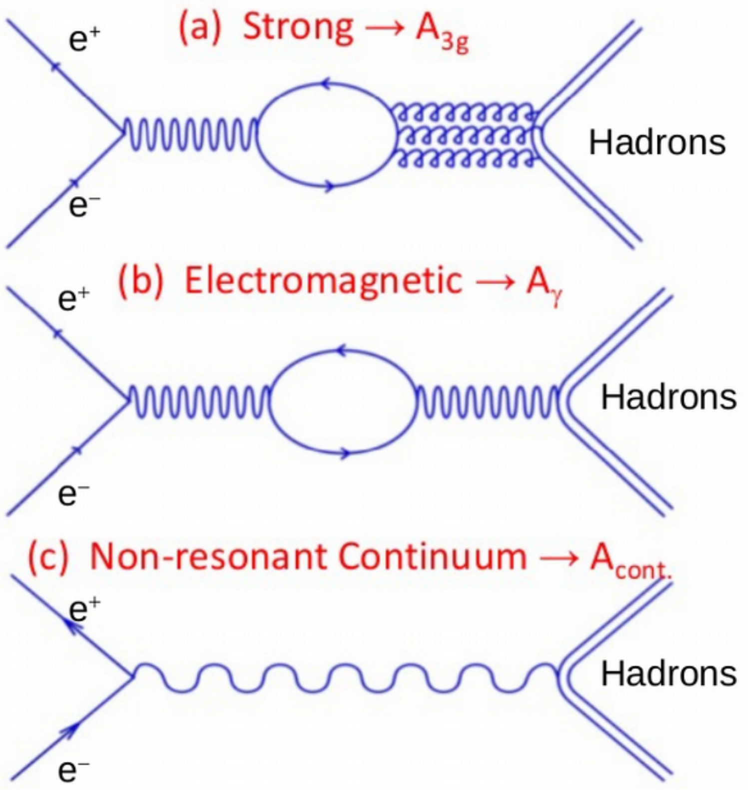
Charmonium weekly meeting, Apr. 10

Outline

- Introduction
- MC generator
- Data vs MC
- Results

Introduction

Relative phase of charmonia



Hadronic cross section around charmonia can be described with three diagrams

Experimental and theoretical agreement around EM contributions

Still questions around the strong (A_{3g}) amplitude:
- pQCD predicts almost real
- experiments have different results for J/ψ, pointing towards 90° relative phase

An additional motivation

From the experimental point of view, based on $SU(3)_F$ and isospin breaking violation models:

- At J/ψ
  - VP (1^-0^-) (e.g. $J/\psi \to \rho\pi$) phase = 106° ± 10°
  - PP (0^-0^-) (e.g. $J/\psi \to \pi\pi$) phase = 89.6° ± 9.9°
  - BB (½ ½) (e.g. $J/\psi \to p\bar{p}$) phase = 89° ± 8°

- At $\psi(2S)$
  - VP (1^-0^-) phase = 159° ± 12°
  - PP (0^-0^-) phase = 95° ± 11°

Experiments points towards a non univocal phase for $\psi(2S)$
(but highly model dependent)

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Possible explaination of $\rho\pi$ puzzle?

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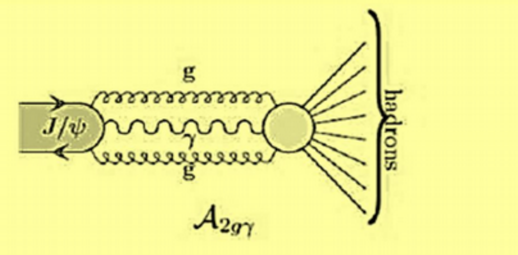
(but highly model dependent)

An(other) motivation

At Changsha workshop Rinaldo presented a model to explain the value of the relative phase in charmonium

The Sounds of Silence
An attempt to explain the anomalous
J/ψ strong decay phase δ



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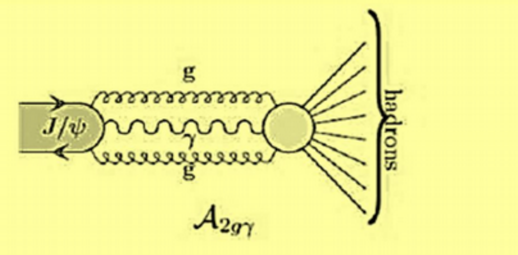

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A new attempt to explain the anomalous
J/ψ strong decay phase
Exploiting $\alpha_S(s_{tl})$ Imaginary Part

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This set of analysis can test this model

QQ_{bar}	$\|\delta(M)\|_{exp}$	$\mu^2 \approx \Lambda^2$	$\mu^2 \approx M_\Phi^2$
Φ	$\|163 \pm 7\|^0 - \delta_\omega$	-170.	-170.
J/ψ	$\|85 \pm 4\|^0$	-66.	**-84.**
$\psi(3686)$	(?)	-61.	-81.
$\Upsilon(1S)$	~ $\|64\|^0$	-44.	-68.

Status of J/psi analyses

Several analyses are on-going:

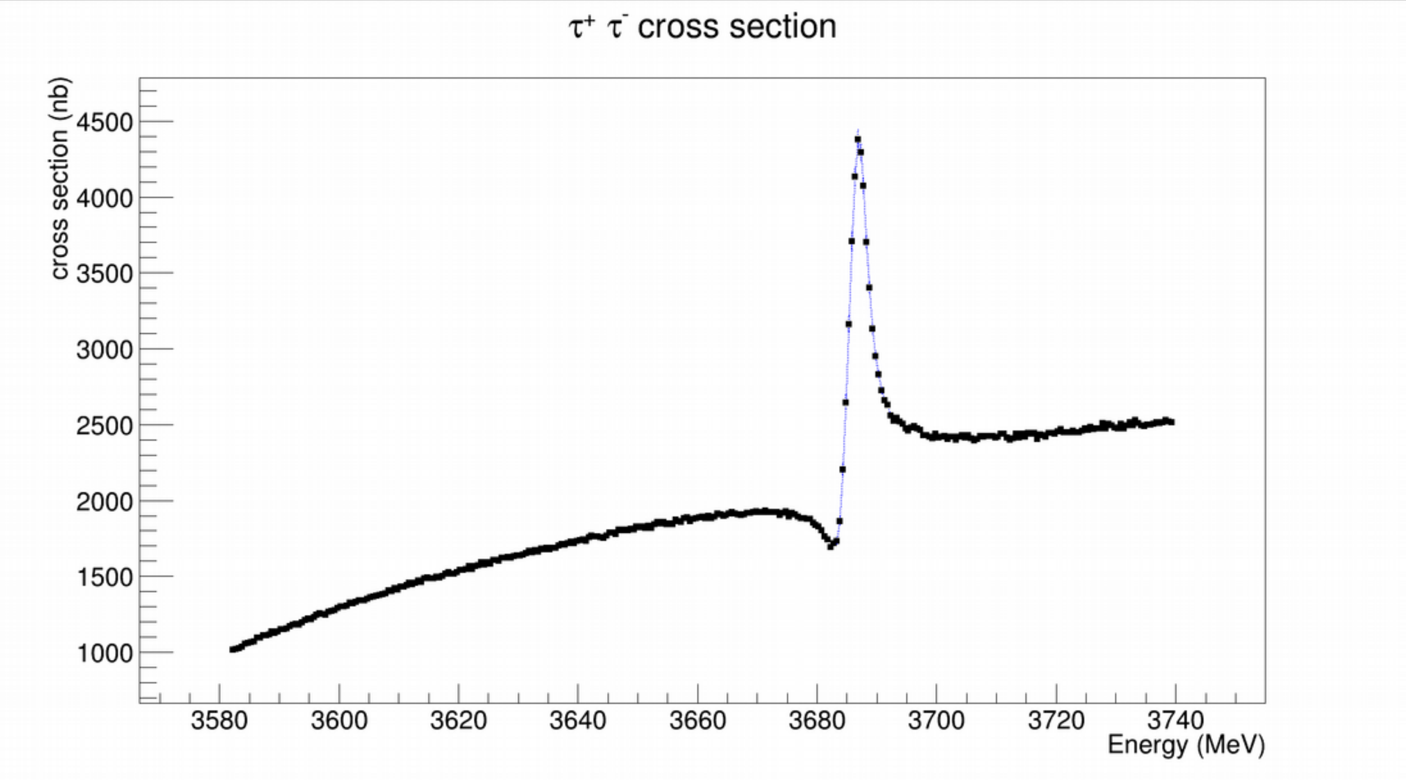
- Yadi Wang's $\mu^+\mu^-$ and 5π study has been published
- Marco Destefanis $p\bar{p}$ study is in Memo stage, ready for a newer version of the memo: results are consistent with other BESIII measurements
- Francesca De Mori K^+K^- study is finalizing the memo after finding consistent results in psi(2S) → π+π- J/psi → π+π- K+K- study of the branching ratio
- I started once $\Lambda\bar{\Lambda}$ analysis, it can be helpful to verify if some differences arise when hyperon are considered (but very little effort)

Which channels?

- Plan to measure the relative phase in the largest number of channels possible to extract the relative phase in a "**inclusive approach**"
  - Unfortunately, our possibility are very limited by time and manpower constraints
- Golden channel:
  - $\pi\pi J/\psi$
  - $\rho\pi$
  - $\mu\mu$
  - $p\bar{p}$
  - K^*K^0

Phase in $\tau^+\tau^-$?

It is also possible to use the τ mass selection to extract the phase in another pure EM decay



Profit of the experience of the chinese and russian colleagues

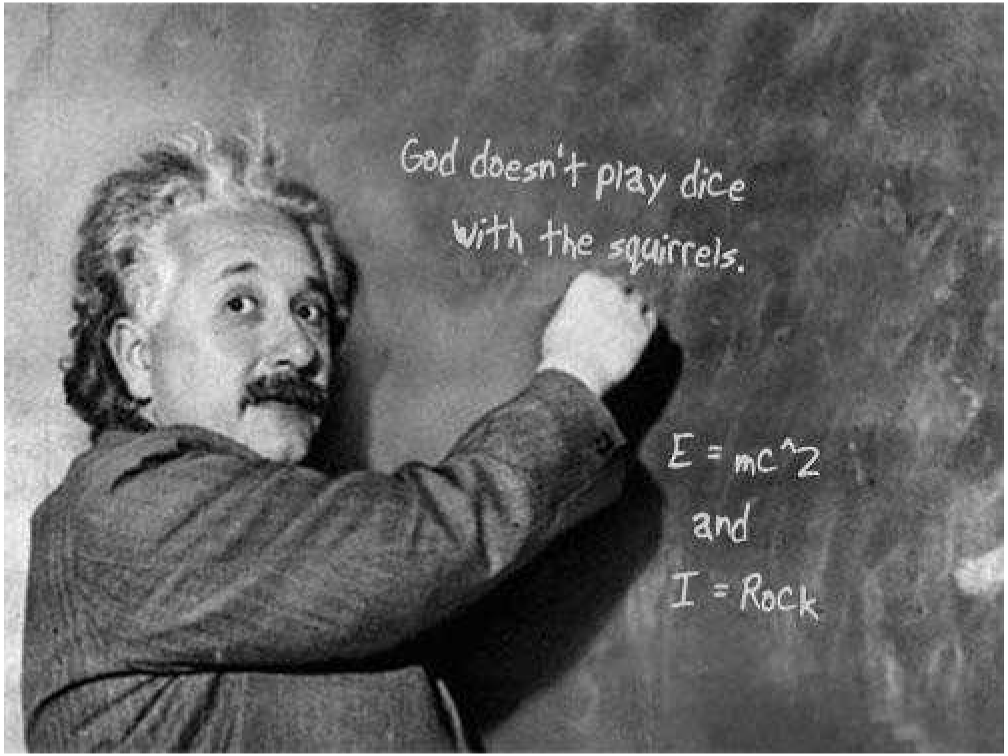
Final tables of runs

Thanks to Zhang Jianyong and BEMS, precise measurements of the beam energies are available.

Requested Energy (MeV)	Requested Luminosity (nb^{-1})	Run number	Energy (MeV)	Spread (MeV)	Luminosity (nb^{-1})
3580	85	55375-55461	3581.543 ± 0.060	1.493 ± 0.060	85665.6
3670	85	55462-55541	3670.158 ± 0.063	1.410 ± 0.053	84719.7
3681	85	55542-55635	3680.144 ± 0.061	1.517 ± 0.060	84814.5
3683	55	55636-55662	3682.752 ± 0.115	1.710 ± 0.104	28668.3
-	-	55663-55690	3684.224 ± 0.119	1.547 ± 0.122	28651.6
3685.5	25	55691-55716	3685.264 ± 0.105	1.478 ± 0.111	25982.8
3686.6	25	55717-55737	3686.496 ± 0.120	1.594 ± 0.117	25055.1
3690	70	55738-55795	3691.363 ± 0.075	1.541 ± 0.074	69374.6
3710	70	55796-55859	3709.755 ± 0.074	1.460 ± 0.075	70326.7

Reconstructed data:
/bes3fs/offline/data/704-1/psipscan1805/dst

All data also available in Torino servers
/media/bespanda/dati_bes/dati_scan/phasepsipscan/
/home_bes009/mdestefa/lists/psip_phase



MC generators

J/psi case

- For J/psi we can use Babayaga, a permille level ISR generator
- We have applied some modifications both on Babayaga and BOSS
  - It was quite a long process
  - But we are successfull
- Slow generation of ISR once
- Fast fitting routine
  - available in fortran and C++, results are compatible

BESIII generator

- KKMC + BesEvtGen
- ConExc
- Babayaga
- Phokhara
- Etim

BESIII generator

- KKMC + BesEvtGen
- ConExc
- ~~Babayaga~~
- ~~Phokhara~~
- Etim

Cannot reproduce all the interesting final states

Etim

- Created by Rinaldo
- Advantage:
  - We know exactly what is inside (if you can read fortran)
  - We have already tested at J/psi that the prediction are in good agreement

- Main disadvantage:
  - It is custom, not official, need lot of counterchecks from the review!

ConExc

- Extract the ISR contribution from an iterative study of the lineshape of the cross section:
  - Start with flat lineshape
  - Iterate until variation of the i-1th and ith step is below a certain threshold (0.1 %), that is assumed also as systematic error

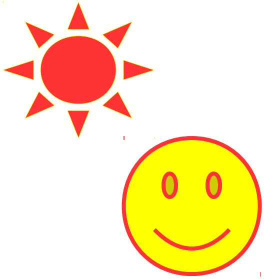
- It can be quite time-demanding
- But has all the final states already included

- Ping RongGang is always very willing to help
  - I haven't directly spoken with him about this yet

谢谢！

KKMC + BesEvtGen

- Advantage: it is official
- A recent version allow to save the information for the ISR/FSR generation, set the maximum ISR energy
  - We need: weight + energy after ISR
  - Then we can repeat the same procedure as for Babayaga!



- Unfortunately it seems to work only around Y(4220)
  - I have spoken with Sun Zhentian in Changsha, he is very willing to collaborate!

谢谢！

KKMC + BesEvtGen

- In the meantime, we shall start to generate some events to perform data quality validation, first cuts

- How to proceed? As suggested to me long-ago by
  - Copy KKMC in the working area
  - Modify the share files by setting the mass of psi(2S) to the central value of the energy considered
  - Modify the decay card accordingly
  - Add “GenerateJpsi = true” option in the jobOptions of the simulation

Examples

```
#include "$OFFLINEEVENTLOOPMGRROOT/share/OfflineEventLoopMgr_Option.txt"

//*************job options for generator (KKMC)***************
#include "$KKMCROOT/share/jobOptions_KKMC_3681.txt"
KKMC.CMSEnergy = 3.680144;
KKMC.BeamEnergySpread=0.001517;
KKMC.NumberOfEventPrinted=1;
KKMC.GenerateJpsi=true;
KKMC.GeneratePsiPrime=true;
KKMC.ThresholdCut = 3.37684;
KKMC.TagISR = 1;
KKMC.IHVP = 1;
//KKMC.ModeIndexExpXS = -2;

//*************job options for EvtGen***************
#include "$BESEVTGENROOT/share/BesEvtGen.txt"
EvtDecay.userDecayTableName = "pipijpsi.dec";
```

```
KKMC.ResParameterRh3 = {1.720e0, 250e-3, 0.0e-6};
// Omega(783)
KKMC.ResParameterOme = {0.78265e0, 8.49e-3, 0.60e-6};
// Omega(1419) --> omega'
KKMC.ResParameterOm2 = {1.419e0, 174e-3, 0.00e-6};
// Omega(1649) --> omega"
KKMC.ResParameterOm3 = {1.649e0, 220e-3, 0.00e-6};
// Phi(1020)
KKMC.ResParameterPhi = {1.01942e0, 4.46e-3, 1.33e-6};
// Phi(1680) --> Phi'
KKMC.ResParameterPh2 = {1.680e0, 150e-3, 0.00e-6};
// J/Psi(3097)
KKMC.ResParameterPsi = {3.096916e0, 0.0929e-3, 5.55e-6};
// Psi(3686)
KKMC.ResParameterPs2 = {3.680144e0, 0.304e-3, 2.35e-6};
// Psi(3770)
KKMC.ResParameterPs3 = {3.77315e0, 27.2e-3, 0.262e-6};
```

THESE ARE THE EVENTS YOU ARE SEARCHING FOR

$$e^+e^- \to \pi\pi J/\psi$$

$$J/\psi \to e^+e^-$$

MC and BOSS version

- BOSS version: 7.0.4
- 20000 events for each energy value to estimate the efficiency and extract the event selection
  - Both real energy and spread are used in the simulation

Energy (MeV)	Spread (MeV)
3581.543 ± 0.060	1.493 ± 0.060
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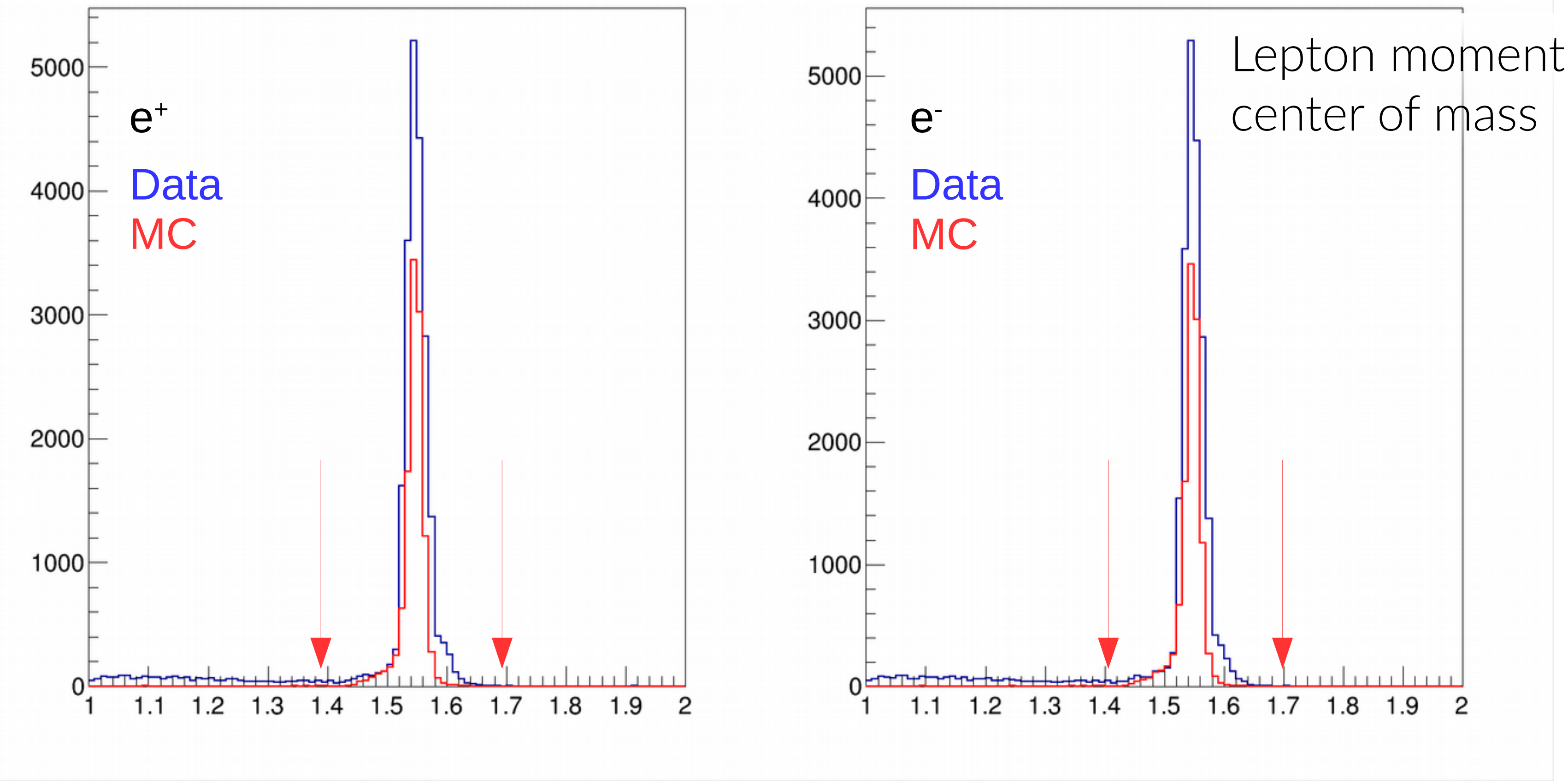
3709.755 ± 0.074	1.460 ± 0.075

- Selection based on PipiJpsialg on BOSS repository:
  - We will move to our algorithm soon

Data – MC comparison @ 3681 MeV



Lepton momentum in the J/psi center of mass

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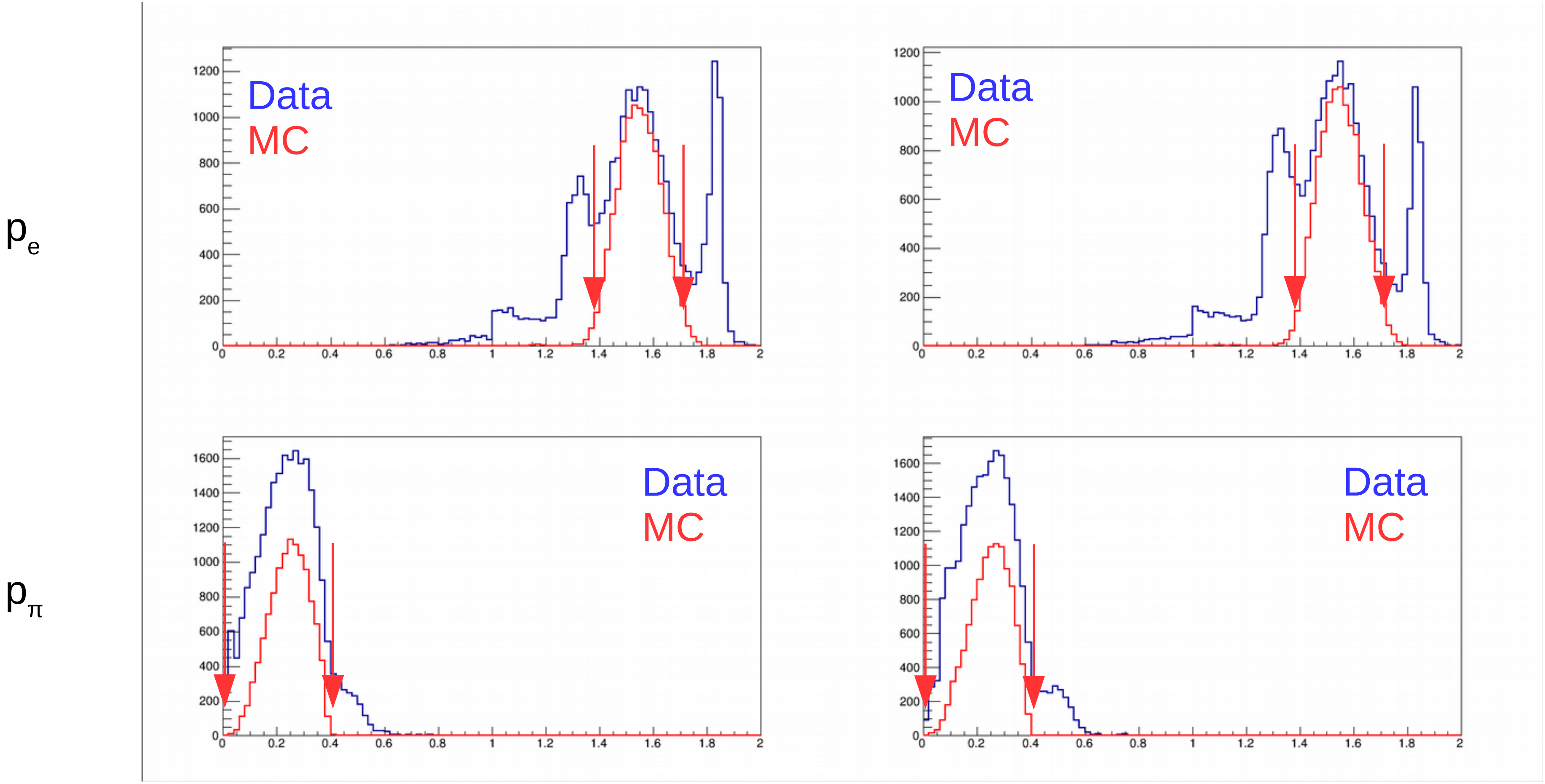
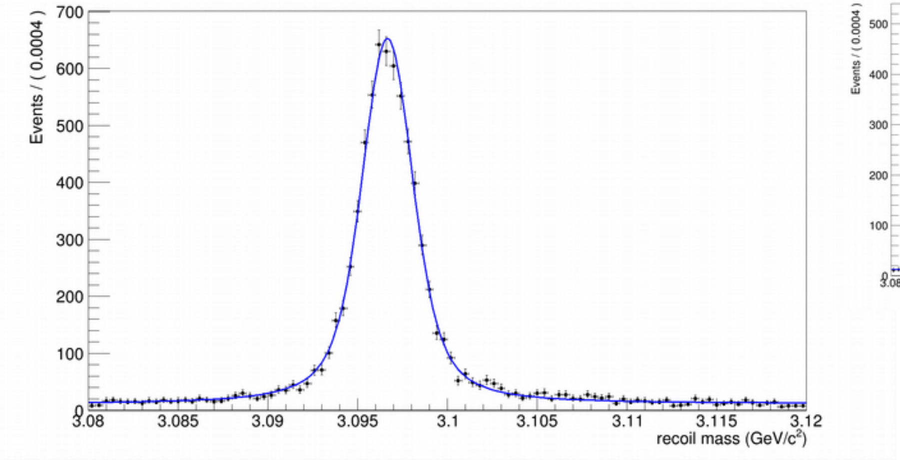


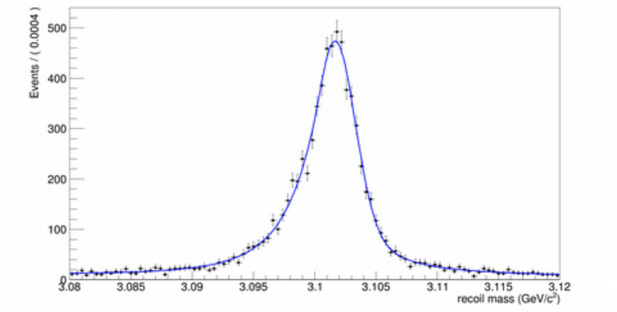
Preliminary efficiencies

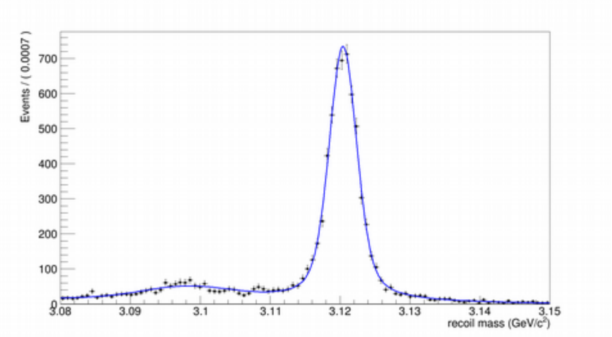
Fit to the ππ recoil mass

Energies before(on) the peak



Energies above the peak

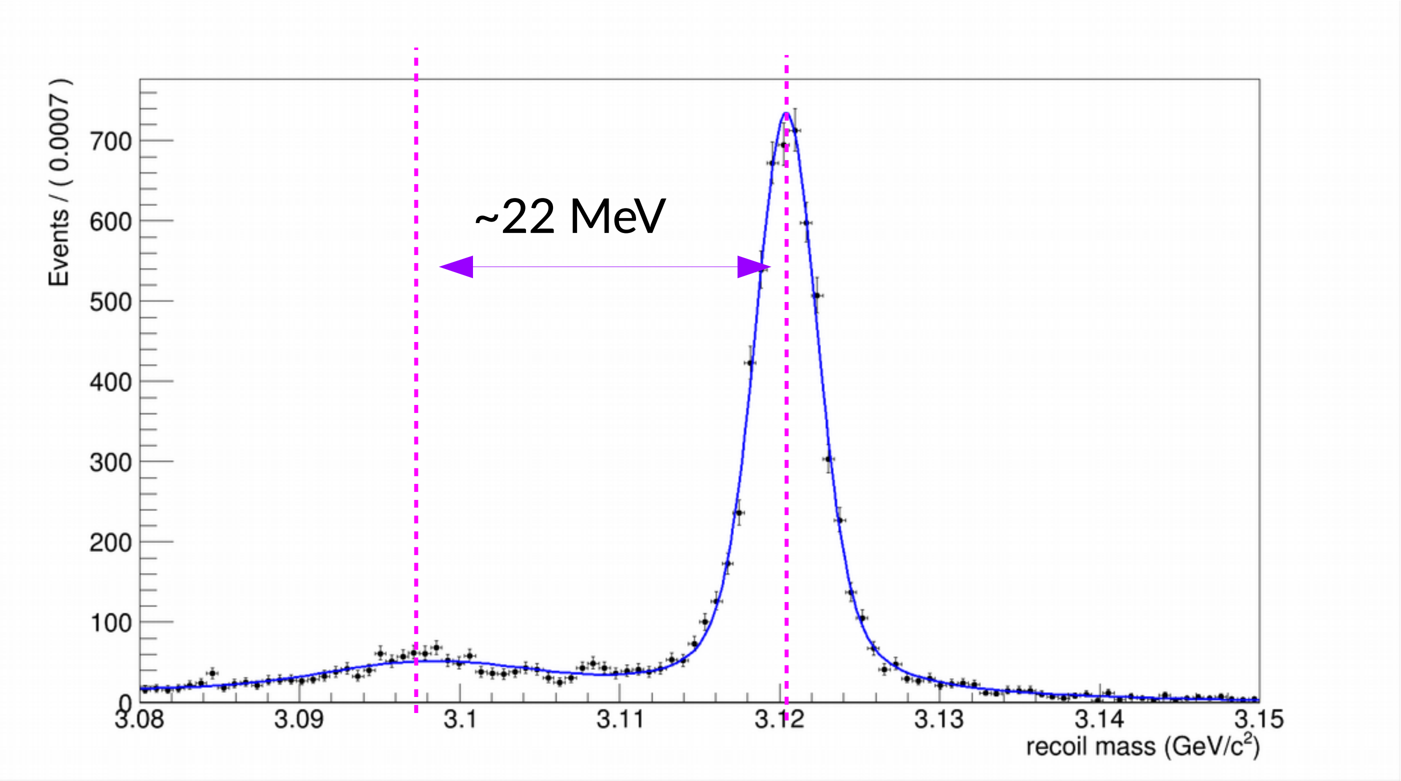




Voigtian distribution +
First order Chebychev

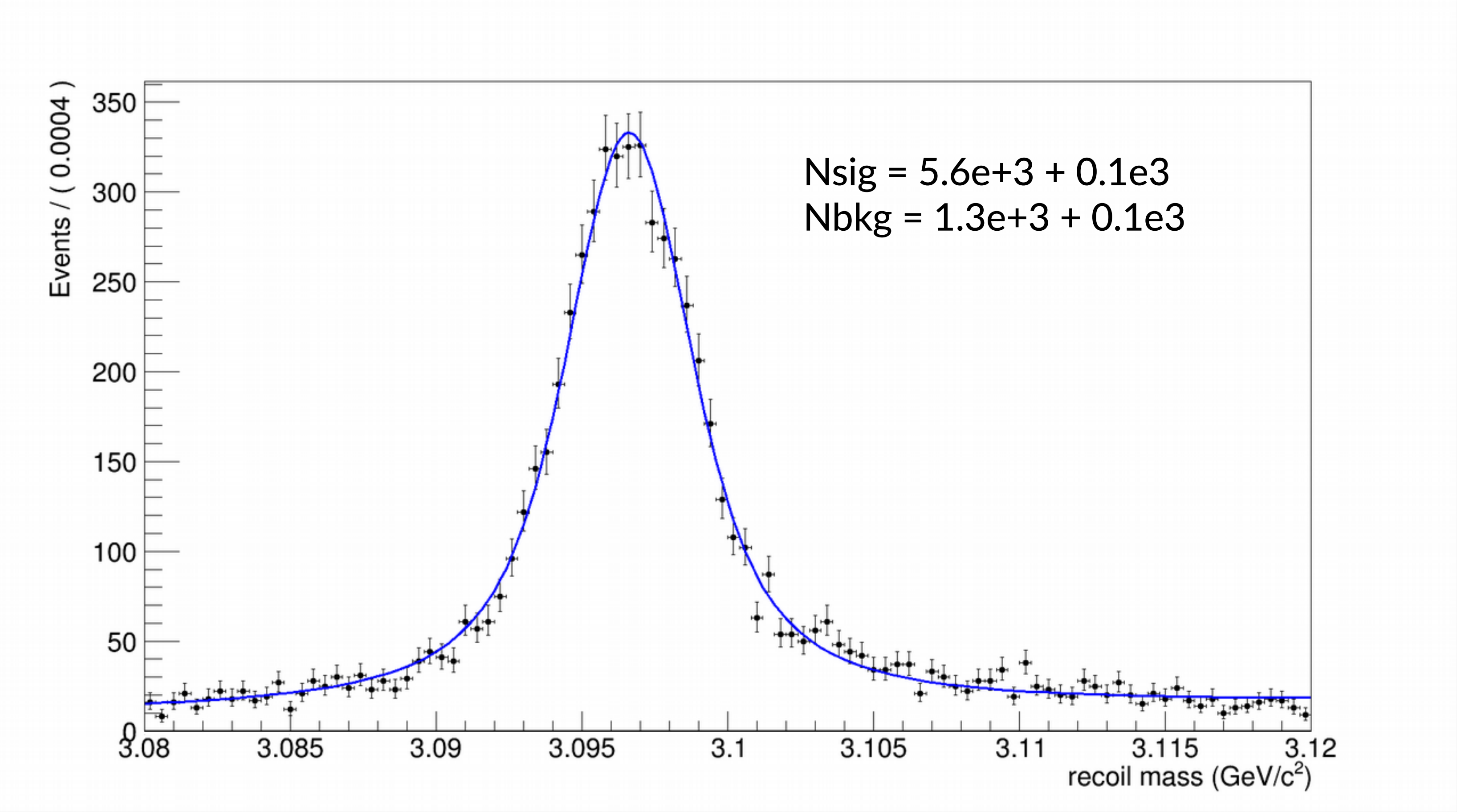
More complicated pattern
due to ISR return

Energy above the peak – ISR effect



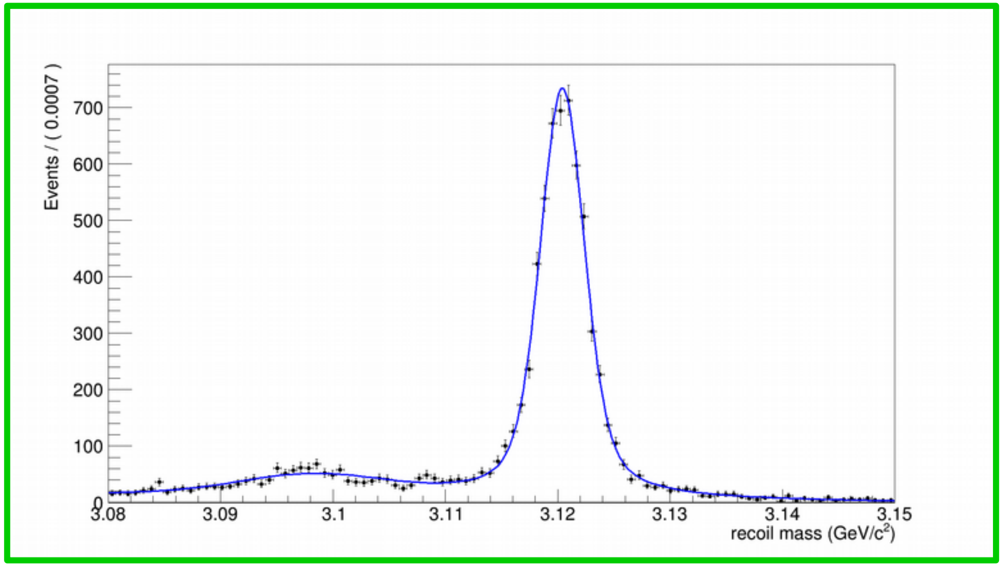
ISR contribution shifts the peak of about the same difference between the center of mass energy and the nominal peak of ψ(2S)

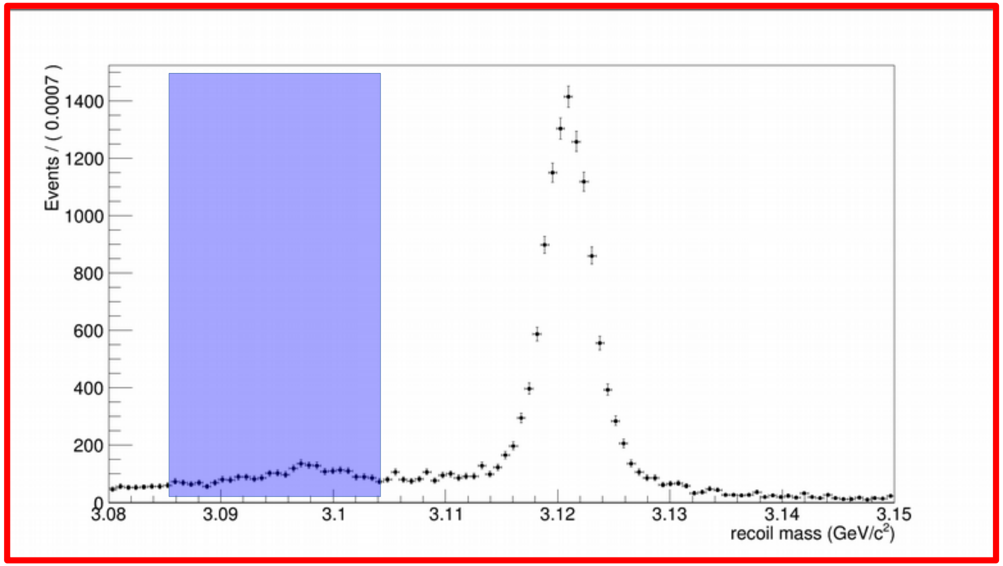
Real data – Fit @ 3681 MeV



Voigtian + Chebychev

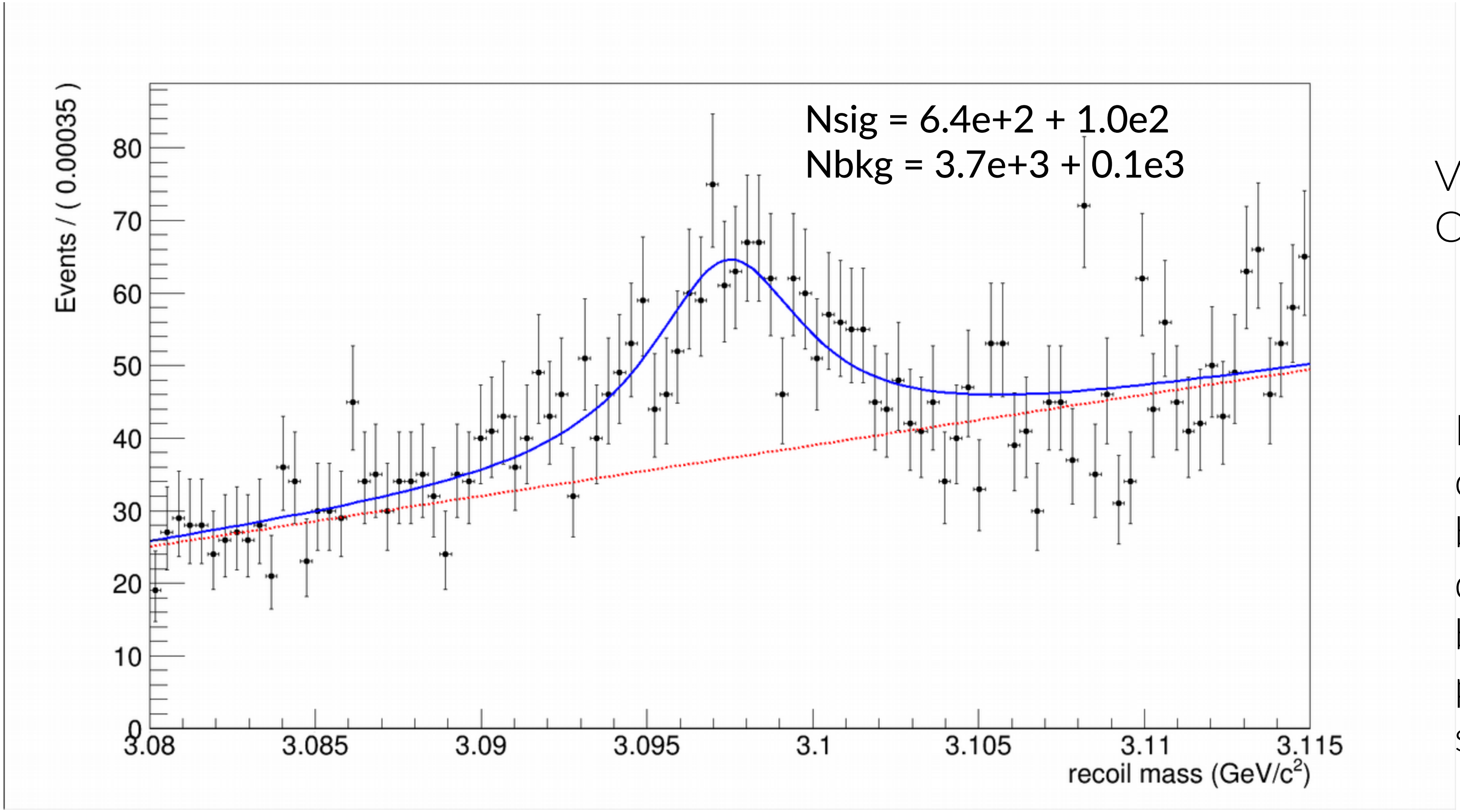
Real data @ 3710 MeV – Full recoil spectrum





Good agreement between MC and data!
Possible to fit only the J/ψ region to search for the signal

Real data @ 3710 MeV – Fit to J/ψ energy region



Voigtian + Chebychev

Final number of events will be determined by fitting both peaks at the same time

Next steps…

- Most urgent: define the proper generator
  - Final fitting routine will change based on this
- Refine the event selection (solve the ISR for events just above the peak) and finalize the cut for $J/\psi \to ee$
- Add the $J/\psi \to \mu\mu$ sample
- Analyse the background
- Final fit to extract the phase
- …


THANKS!