Cross section and phase of e^+e^- → pipiJ/psi in proximity of psi(2S) peak

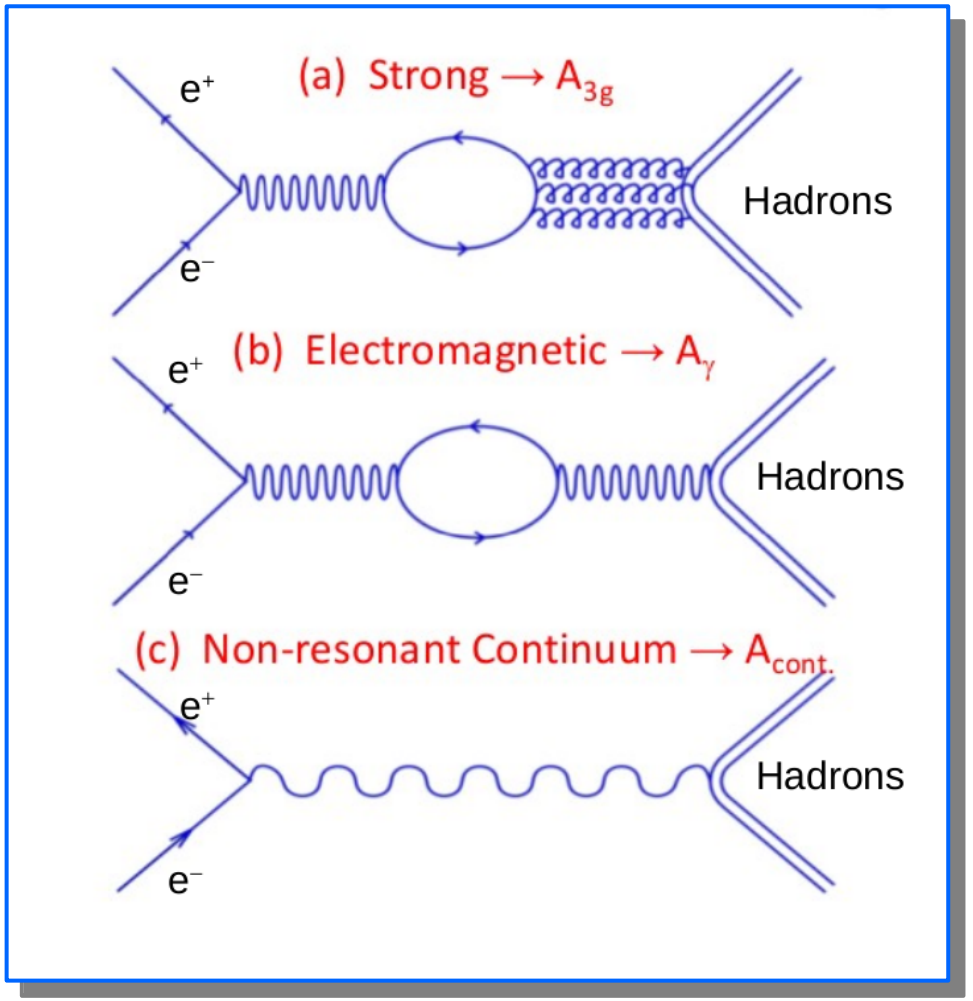
G Mezzadri
INFN Ferrara

Charmonium weekly meeting – Nov 6, 2019

Outline

- Why measure the relative phase of charmonia?
- Event Selection with MC samples
- Data
- Phase measurements with “traditional” fit

Phase measurements



Three possible diagrams can contribute to the process e+e → hadrons

The relative phase is assumed to be zero between continuum and electromagnetic processes.

We would like to extract the phase of the strong amplitude.

While in the case of psi(2S) the phase shall lie around 90°, there is no clear indication on wheter it shall be real or not

Data used

2018 psi(2S) data taking

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

Added also the continuum data at 3.65 GeV (44/pb)

Still missing a measurements of the real luminosities, used the nominal at present time

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 Generator

- BOSS version: 7.0.4
- 20000 events for each energy value to estimate the efficiency and extract the event selection
  - $e^+e^- \rightarrow$ pipiJ/psi, J/psi $\rightarrow l^+l^-$
  - Both real energy and spread are used in the simulation

Energy (MeV)	Spread (MeV)
3581.543 ± 0.060	1.493 ± 0.060
3670.158 ± 0.063	1.410 ± 0.053
3680.144 ± 0.061	1.517 ± 0.060
3682.752 ± 0.115	1.710 ± 0.104
3684.224 ± 0.119	1.547 ± 0.122
3685.264 ± 0.105	1.478 ± 0.111
3686.496 ± 0.120	1.594 ± 0.117
3691.363 ± 0.075	1.541 ± 0.074
3709.755 ± 0.074	1.460 ± 0.075

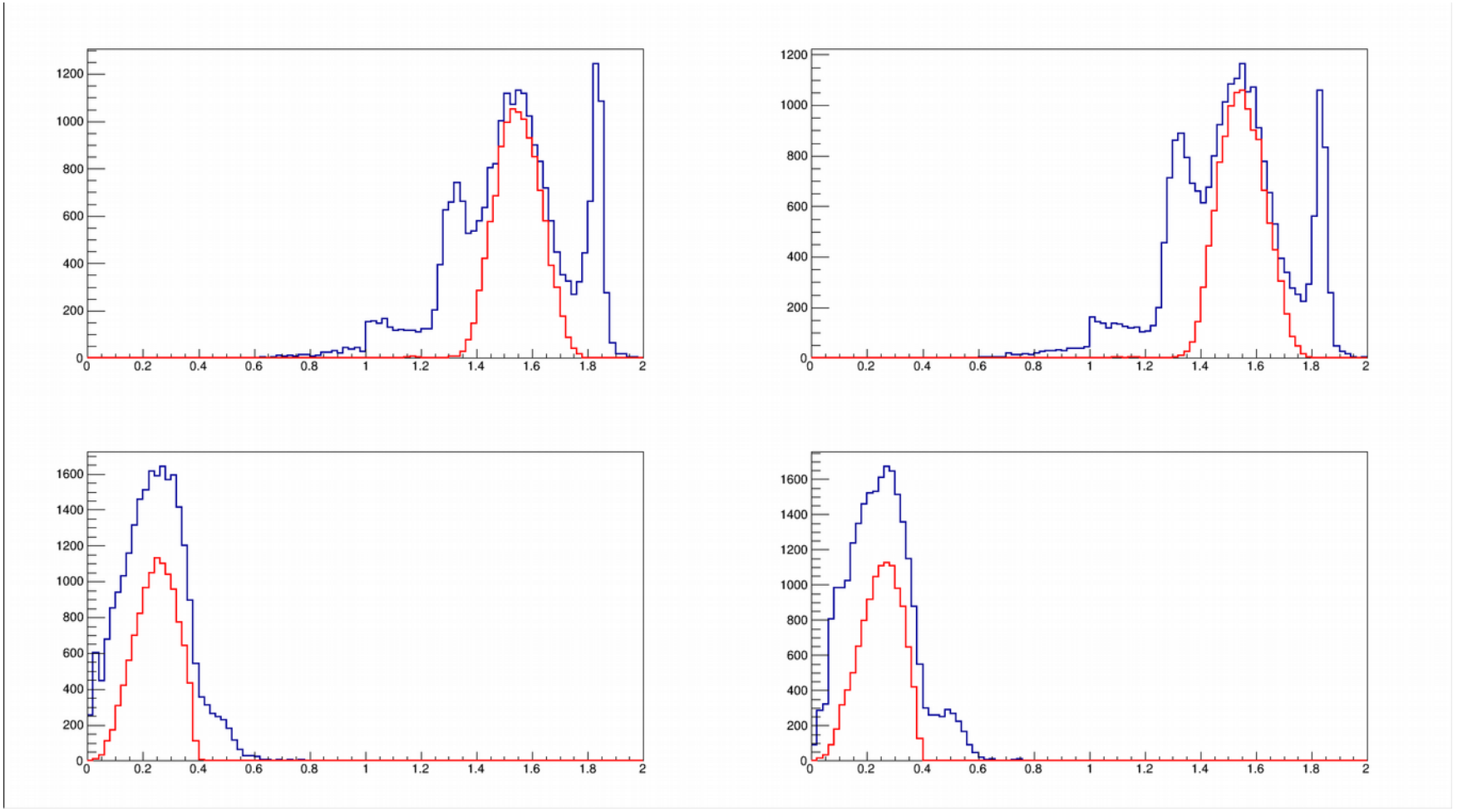
Event Selection

- Event selection follows similar criteria of other pipiJ/psi final state analyses (PRL 118, 092001 (2017))
- Event Selections:
  - 4 charged tracks with 0 net charge
  - $|\cos\theta| < 0.93$
  - $V_{z,poca} < 10$ cm
  - $V_{xy,poca} < 1$ cm
  - **p** > 1.06 – track is a lepton
  - **p** < 0.45 – track is a pion
  - Energy in EMC > 0.35 – lepton is an electron
  - 4c kinematic fit is applied
- Radiative Bhabha and radiative dimuons background are suppressed by a cut on the opening angle between the two pions ($\cos|\theta_{pipi}| < 0.98$) and non-radiative Bhabha events are further suppressed with a cut on the opening angle between the two lepton ($\cos|\theta_{ee}| < 0.98$).

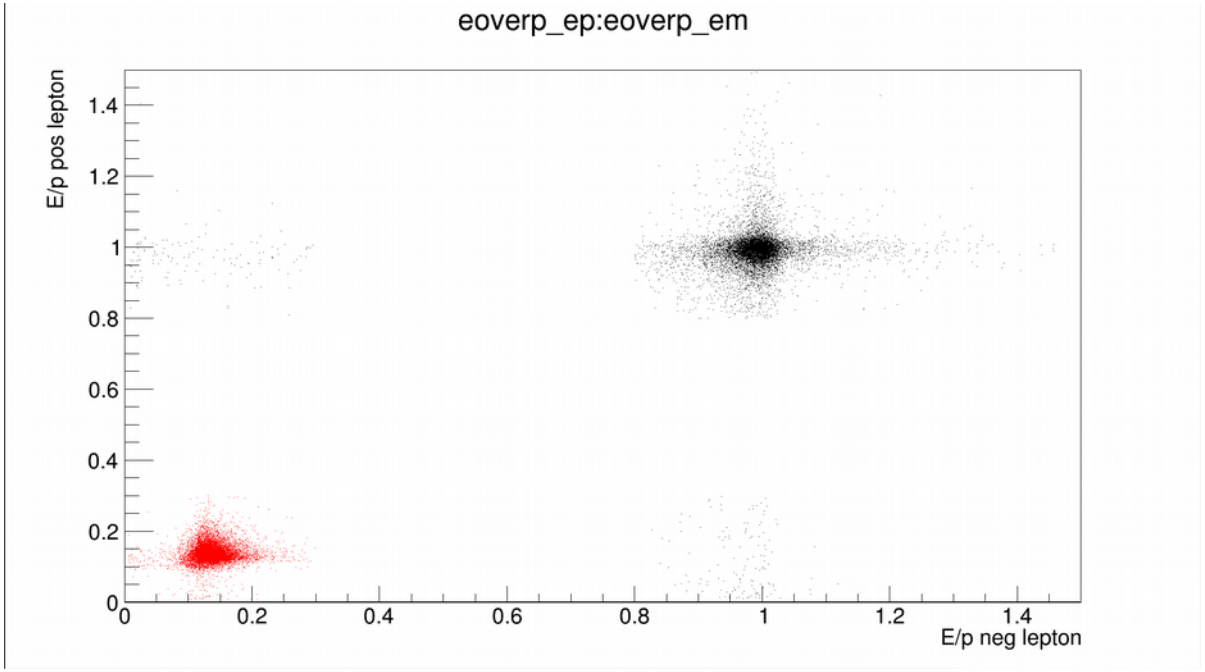
Event Selection

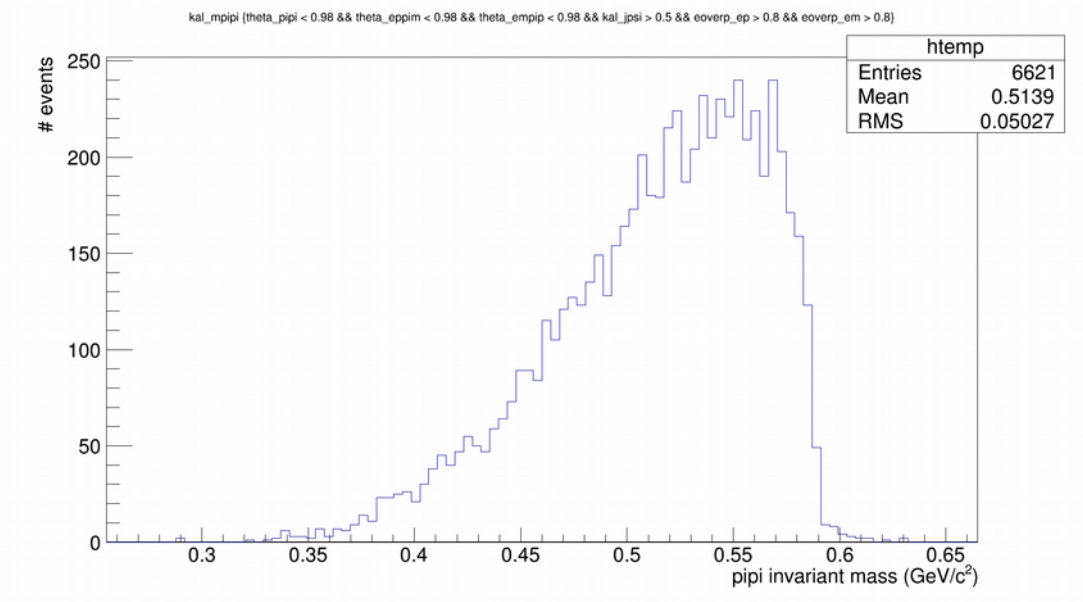
p_l

p_π

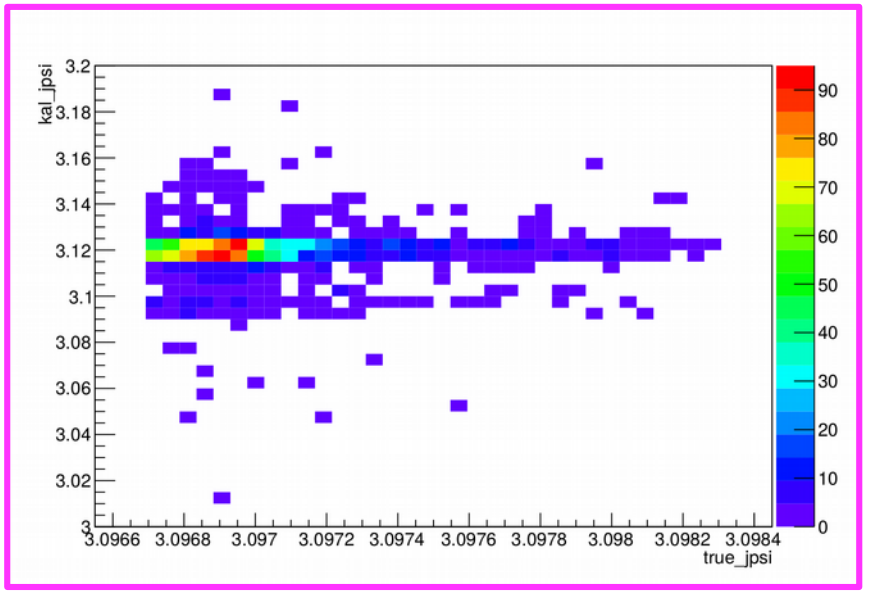


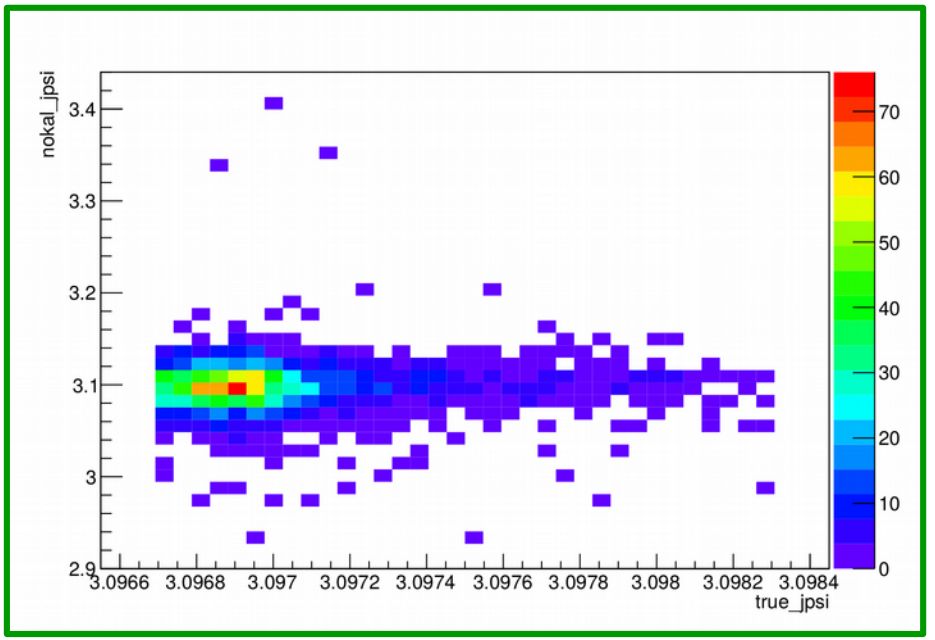
Event Selection





Extracting the number of events



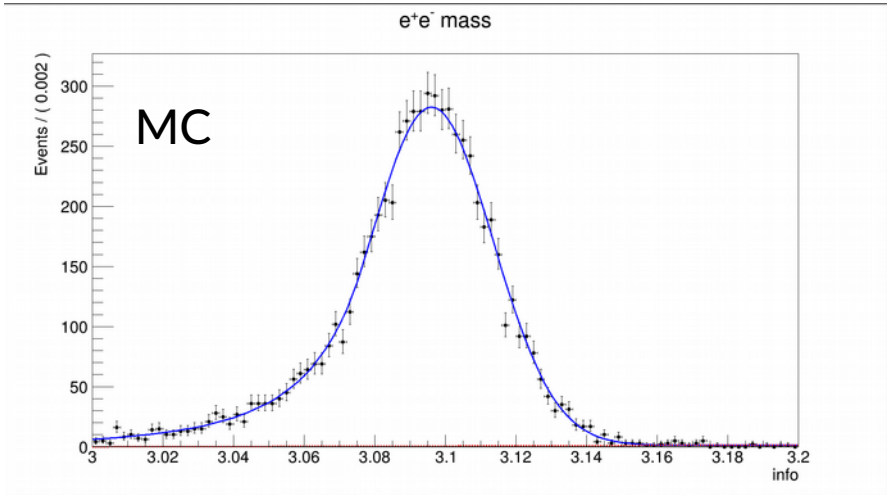


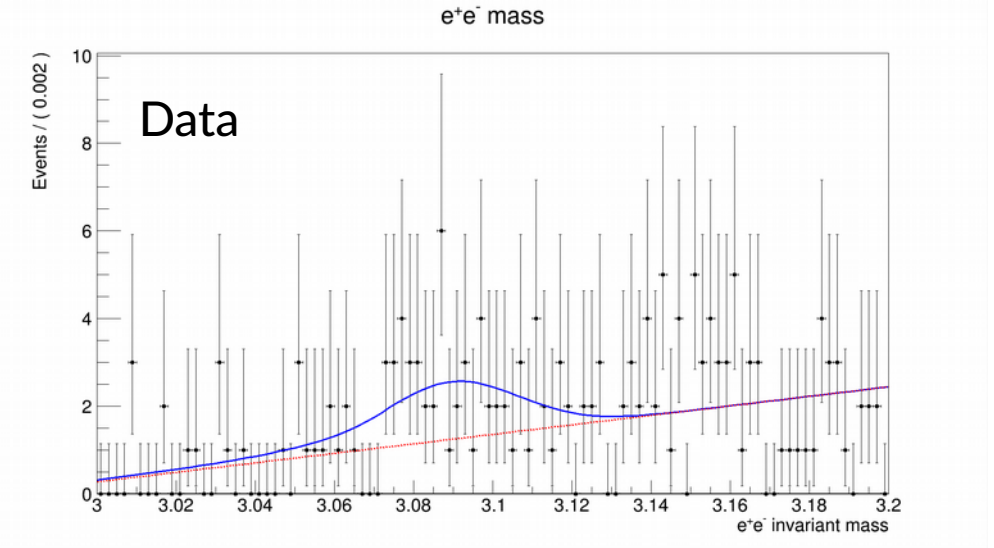
e^+e^- final state

Results with MC and Data

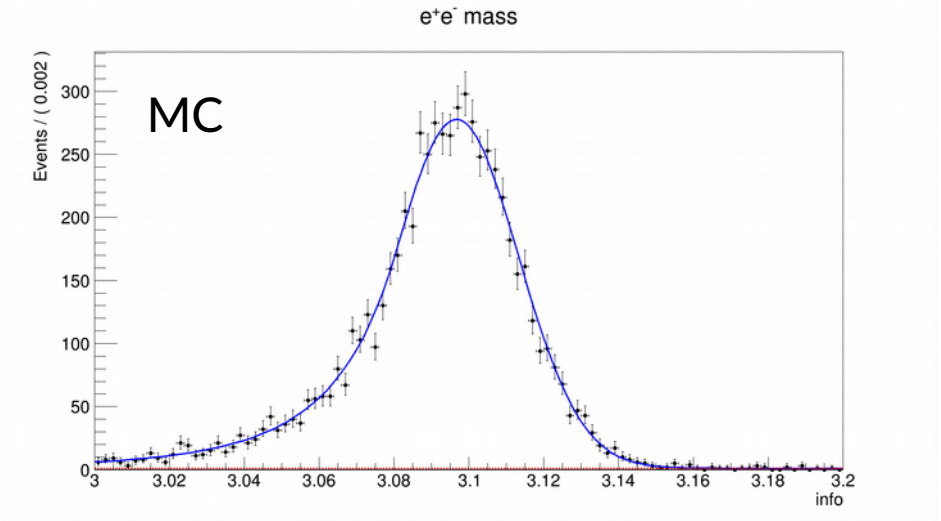
Crystall ball + Chebychev polynomial

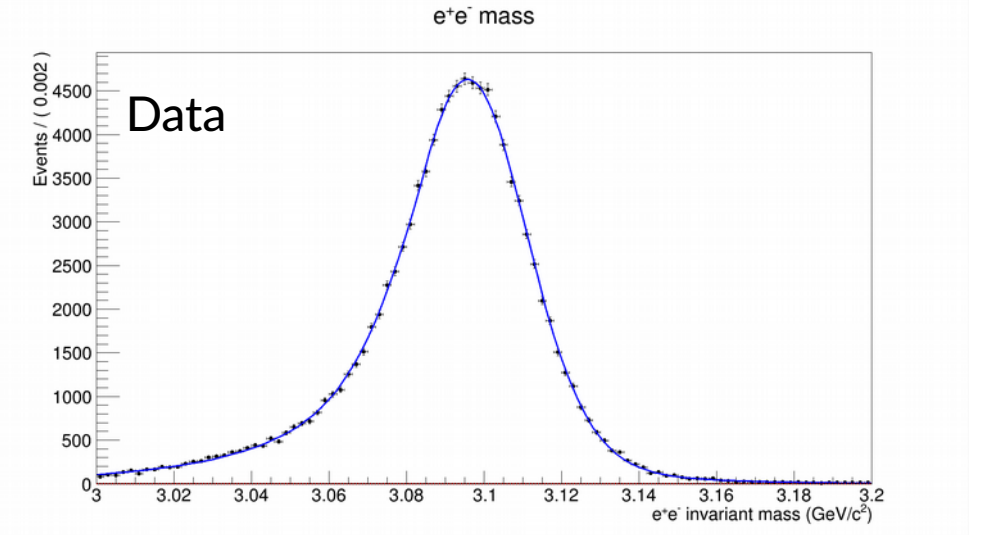
3650 MeV





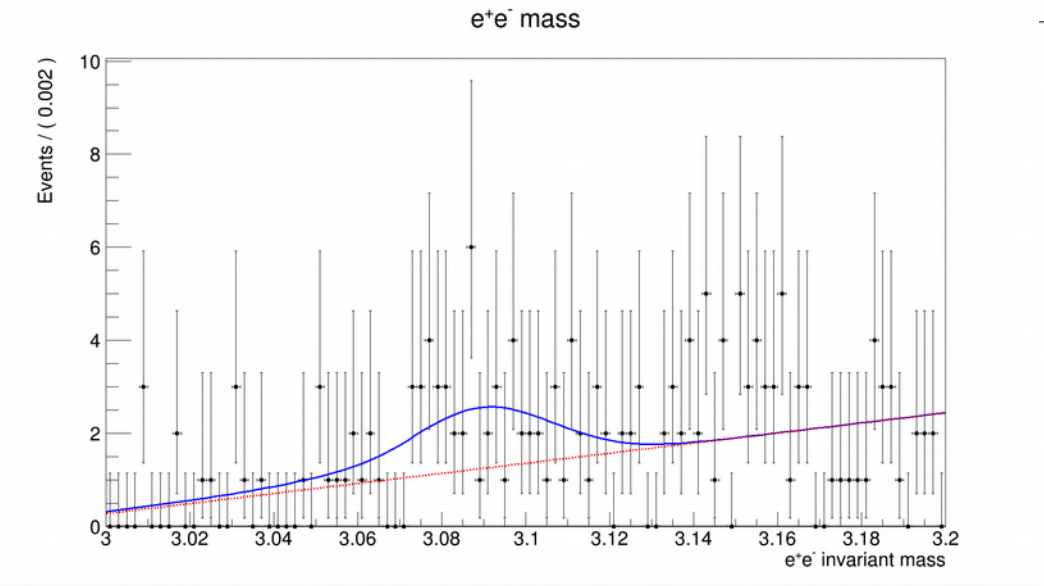
3686.6 MeV

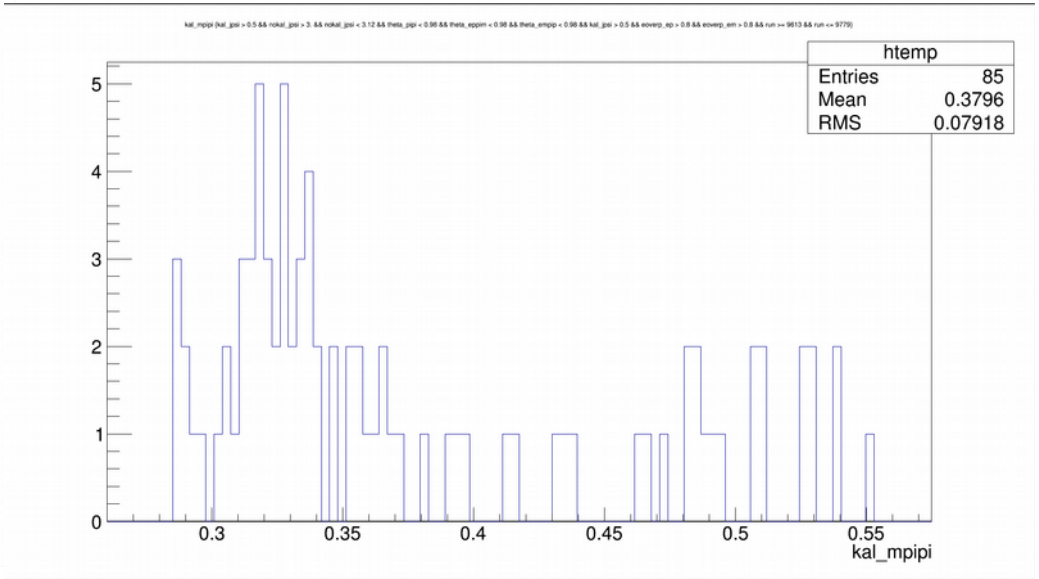




Double Crystall ball + Chebychev polynomial

More on 3650 fit





Investigation on the invariant mass of pipi will help to understand the significance of the signal

Efficiency and number of events

Energy	Events	Efficiency	xsec (pb)
3580	0	32.1 ± 0.3	0
3650	31 ± 11	33.8 ± 0.3	34 ± 12
3670	269 ± 23	33.0 ± 0.3	160 ± 14
3681	2372 ± 56	32.2 ± 0.3	1457 ± 37
3683	9844 ± 107	32.9 ± 0.3	17812 ± 266
3684	48254 ± 230	32.2 ± 0.3	85717 ± 958
3685.5	104348 ± 339	32.1 ± 0.3	209547 ± 2255
3686.6	106896 ± 337	32.1 ± 0.3	223084 ± 2399
3690	23364 ± 169	11.2 ± 0.2	50117 ± 1059
3710	4747 ± 70	11.6 ± 0.2	9748 ± 238.5

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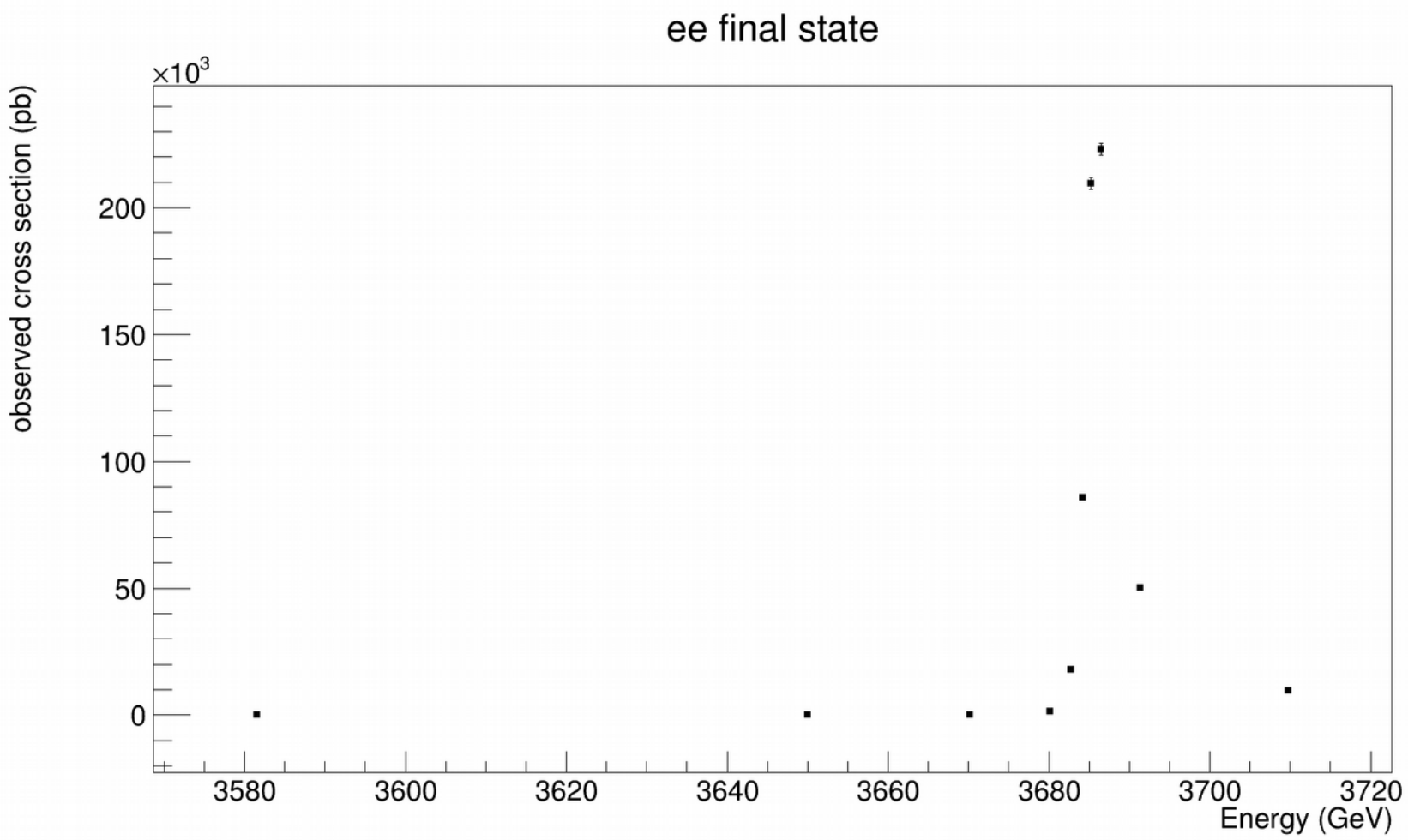
Due to ISR effect – Correction to be addressed

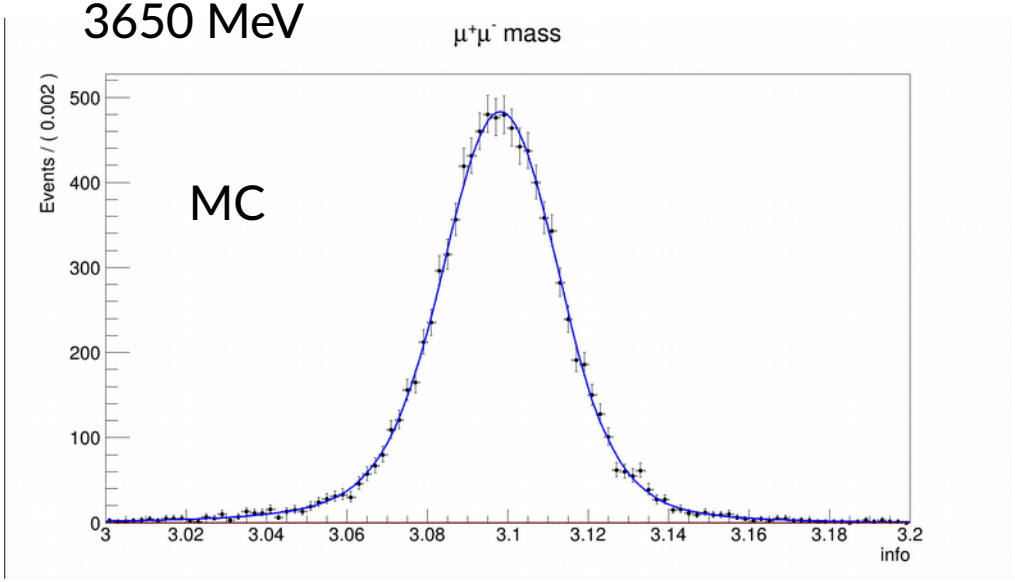
Observed cross section

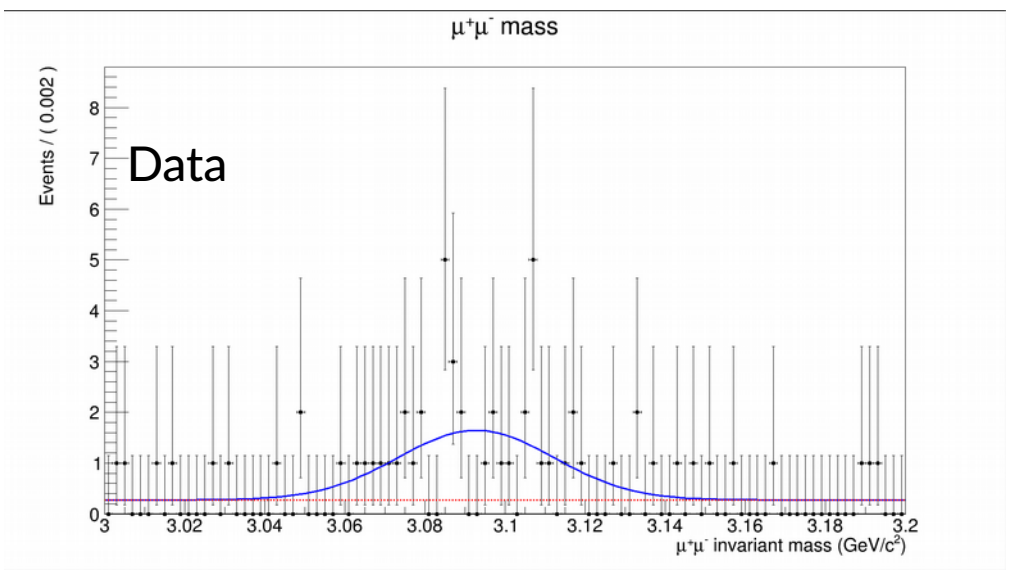


$\mu^+\mu^-$ final state

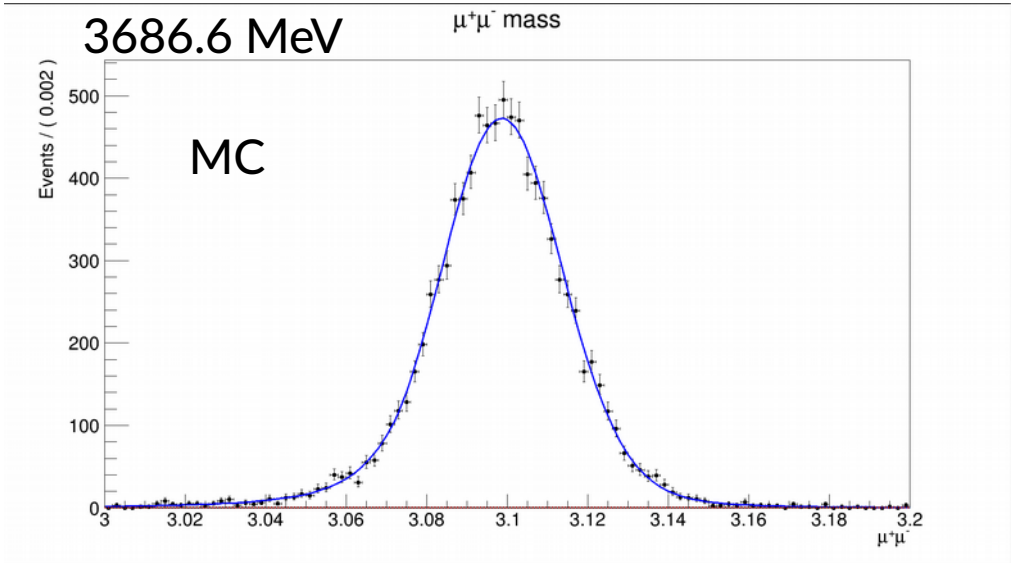
Results with MC and Data

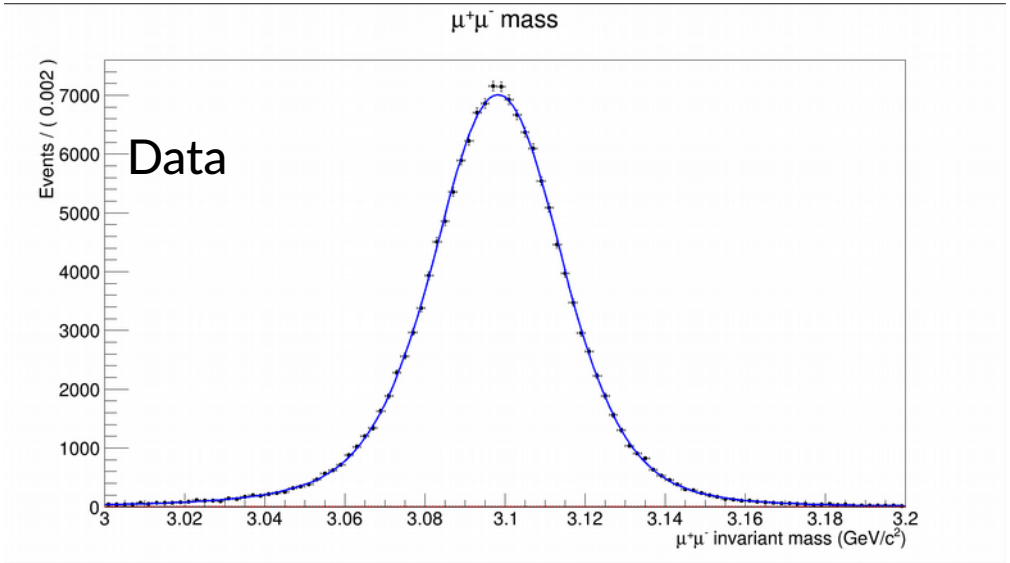
3650 MeV





3686.6 MeV



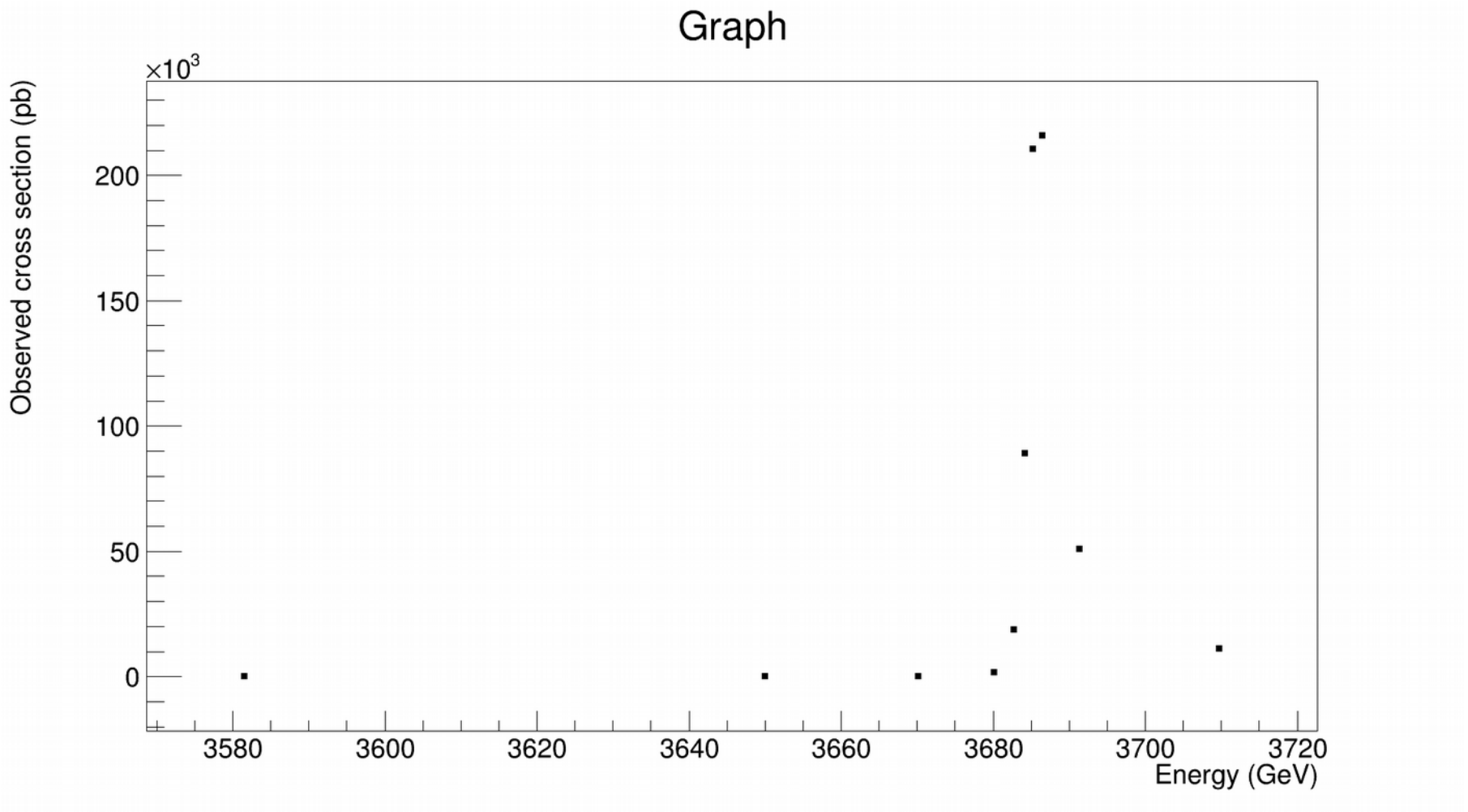


Efficiency and number of events

Energy	Events	Efficiency	xsec (pb)
3580	0	45 ± 0.3	0
3650	33 ± 8	47.4 ± 0.3	26 ± 6
3670	496 ± 29	46.9 ± 0.3	209 ± 12
3681	3682 ± 61	46.2 ± 0.3	1576 ± 29
3683	14725 ± 140	46.2 ± 0.3	18646 ± 227
3684	70462 ± 292	46.3 ± 0.4	89035 ± 773
3685.5	152443 ± 436	46.9 ± 0.4	210492 ± 1694
3686.6	151353 ± 435	47.0 ± 0.4	215949 ± 1734
3690	33638 ± 217	16.0 ± 0.3	50969 ± 890
3710	6683 ± 69	14.2 ± 0.2	11268 ± 247

Due to ISR effect – Correction to be addressed

Observed cross sections



A question on the 1+delta correction

- I tried to use KKMC correction by extracting the output cross section from program with Radiative correction on and off

ON

```
*********************************************************************
*                  KK2f_Finalize  printouts                         *
*      3.65000000                cms energy total        cmsene    a0 *
*           20000                total no of events      nevgen    a1 *
*              ** principal info on x-section **                    *
*     72.57816407  +- 0.47206203  xs_tot MC R-units       xsmc      a1 *
* 473165.24792766                 xs_tot    picob.        xSecPb    a3 *
*   3077.55577077                 error     picob.        xErrPb    a4 *
*      0.00650419                 relative error          erel      a5 *
*     58.61390201                 WTsup, largest WT       WTsup     a10 *
*                  ** some auxiliary info **                        *
*   7648.04705653                 xs_born   picobarns      xborn    a11 *
*      0.31647838                 Raw phot. multipl.                 === *
*      4.00000000                 Highest phot. mult.                === *
*                    End of KK2f  Finalize                          *
*********************************************************************
```

OFF

```
*********************************************************************
*                  KK2f_Finalize  printouts                         *
*      3.65000000                cms energy total        cmsene    a0 *
*           20000                total no of events      nevgen    a1 *
*              ** principal info on x-section **                    *
*    1185.93078938  +- 0.73170933  xs_tot MC R-units       xsmc      a1 *
* 7731543.54578906                 xs_tot    picob.        xSecPb    a3 *
*   4770.29736338                 error     picob.        xErrPb    a4 *
*      0.00061699                 relative error          erel      a5 *
*      1.23479173                 WTsup, largest WT       WTsup     a10 *
*                  ** some auxiliary info **                        *
*   7648.04705653                 xs_born   picobarns      xborn    a11 *
*      0.00000000                 Raw phot. multipl.                 === *
*      0.00000000                 Highest phot. mult.                === *
*                    End of KK2f  Finalize                          *
*********************************************************************
```

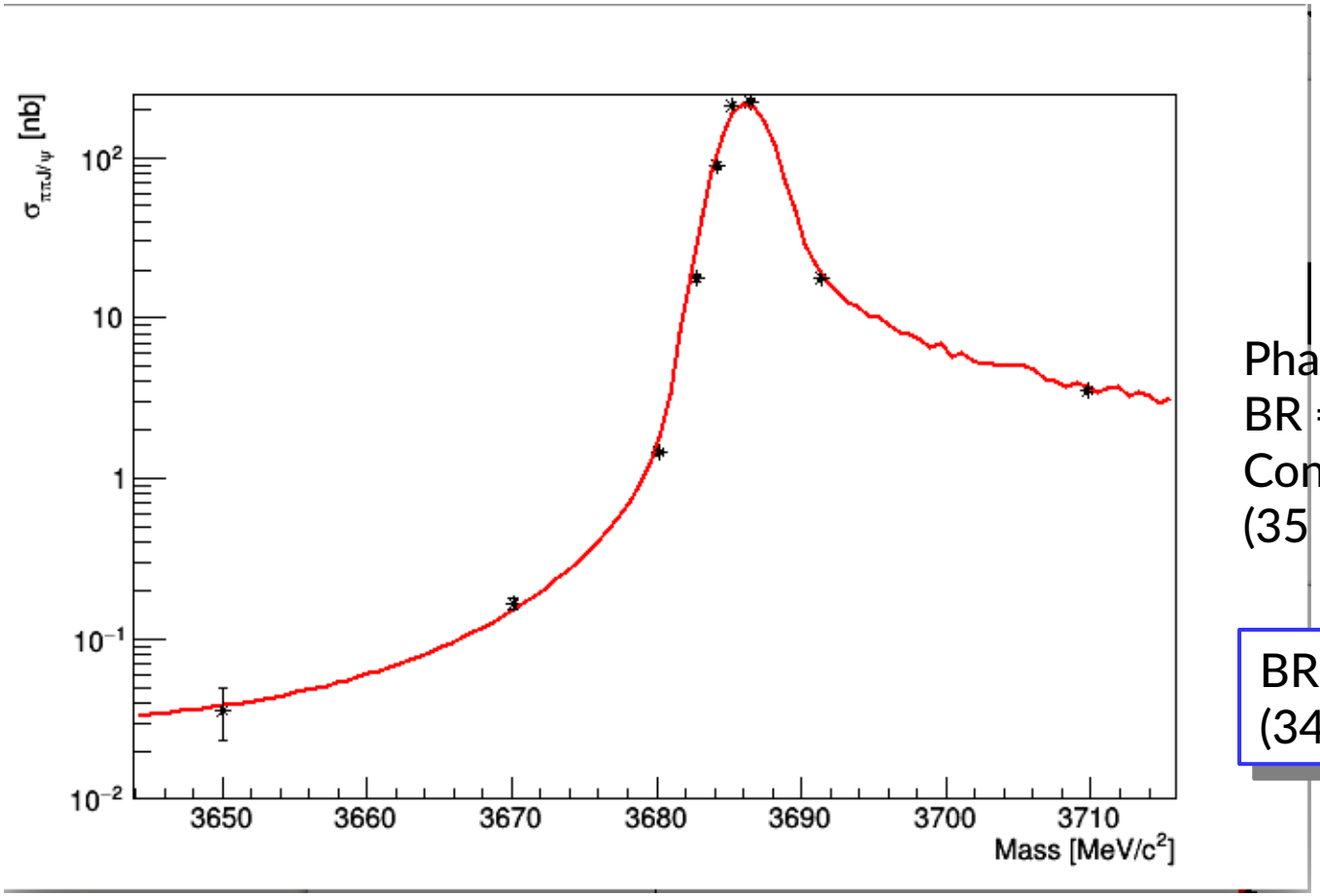
Then I divide the two cross sections (OFF/ON) to get 1+delta.

Is this right?

Phase extraction

$e^+e^- \rightarrow$ pipiJ/psi, J/psi $\rightarrow e^+e^-$

First preliminary result – efficiency fixed at 32% for each point



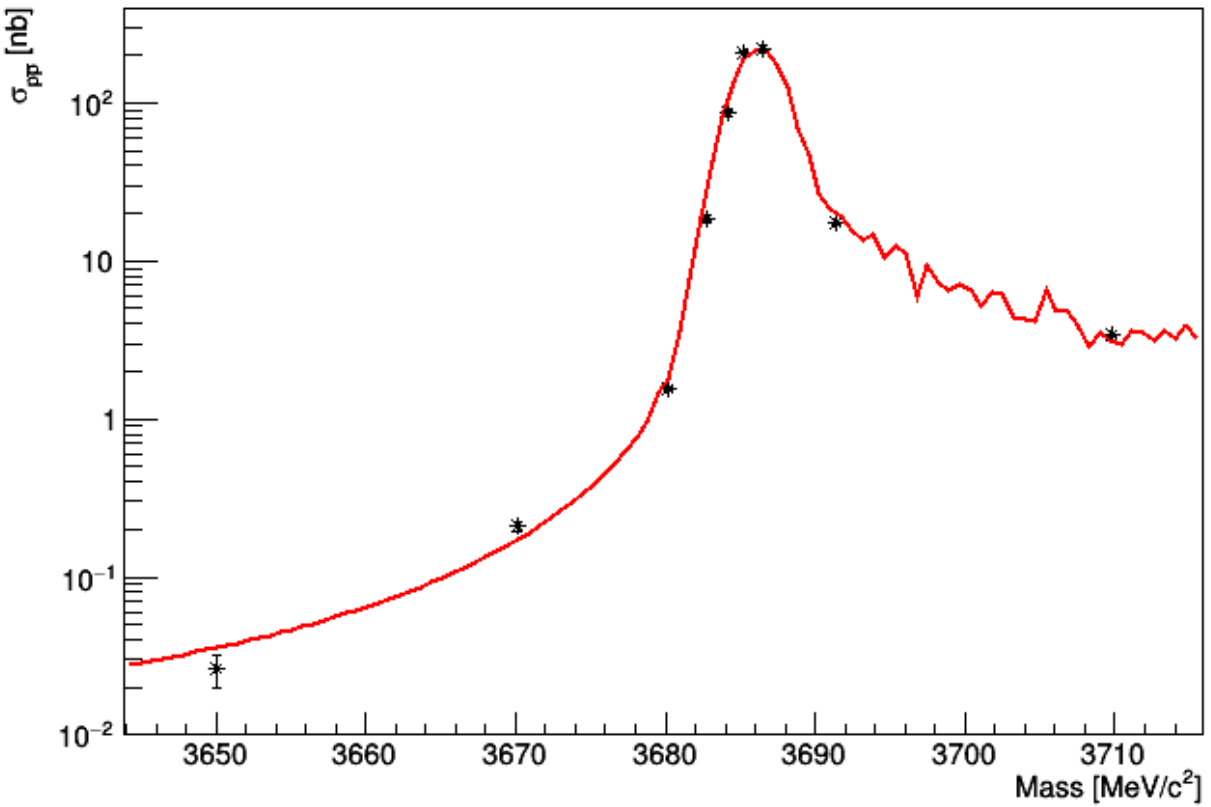
100k extraction per energy

Phase = (119 +/- 5)°
BR = (33.3 +/- 0.2)%
Continuum (@3550) = (35 +/- 21) pb

BR(PDG) = (34.68 +/- 0.3)%

$e^+e^- \rightarrow pipiJ/psi,\ J/psi \rightarrow \mu^+\mu^-$

First preliminary result – efficiency fixed at 47% for each point



10k extraction per energy

Phase = (112 +/- 6)°
BR = (33.1 +/- 0.3)%
Continuum (@3550) = (13 +/- 11) pb

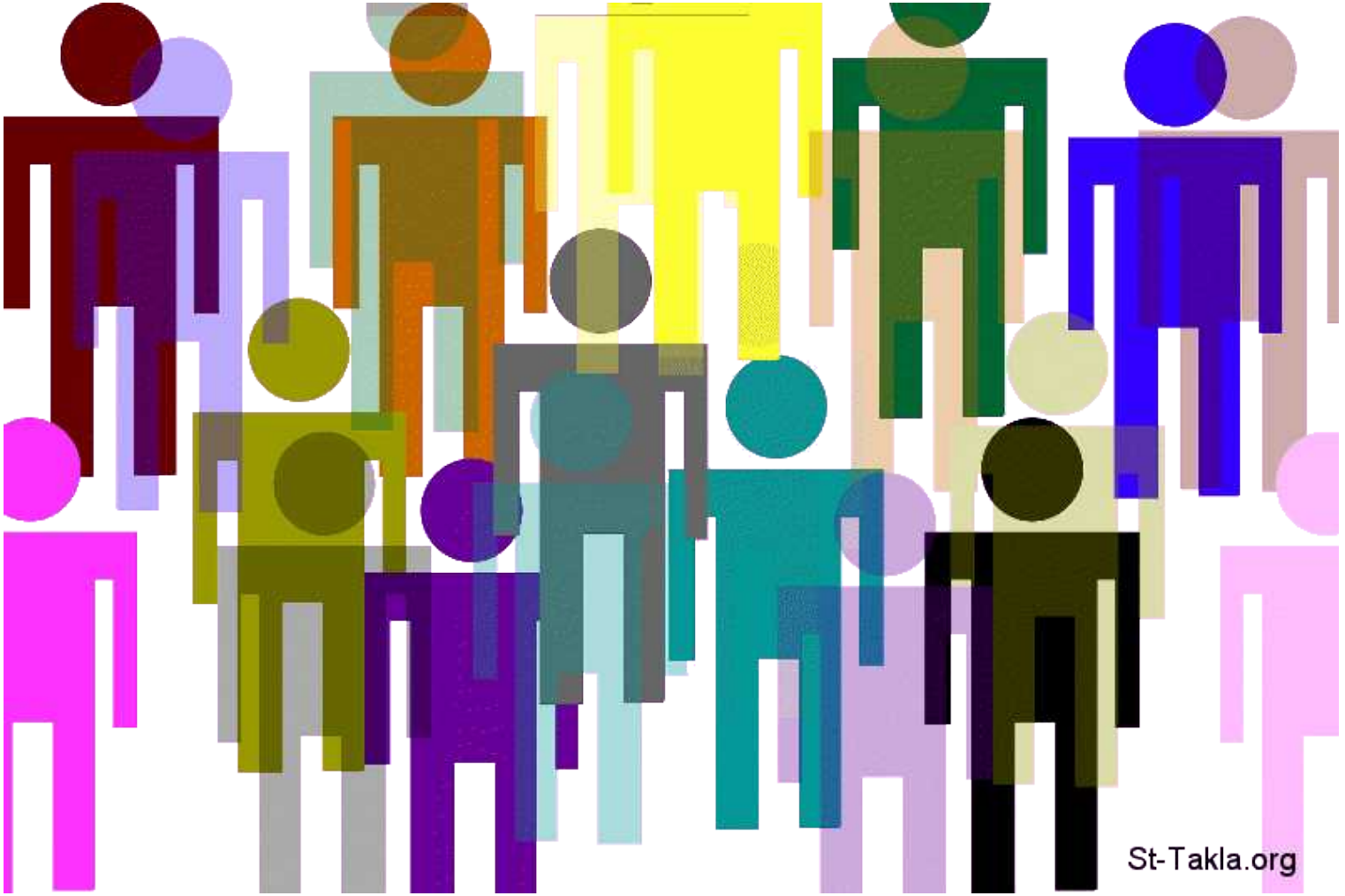
BR(PDG) = (34.68 +/- 0.3)%

Summary and outlook

- Stable event selection since July, finalized also the fitting functions to extract the number of events
- Fit routine, albeit older, converges to compatible results for both final states
  - Only important difference is the continuum, investigation on-going
- Next step:

  1) to study the cross sections:
  - correct the ISR effect with 1+delta correction at the efficiency
  - study the systematics

  2) to extract the phase:
  - Systematics from the previous point
  - Update fit routine to test both sign hypotheses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THANKS