Impact of Additional Radiation on Pion FF Measurement at BESIII: MC Comparison

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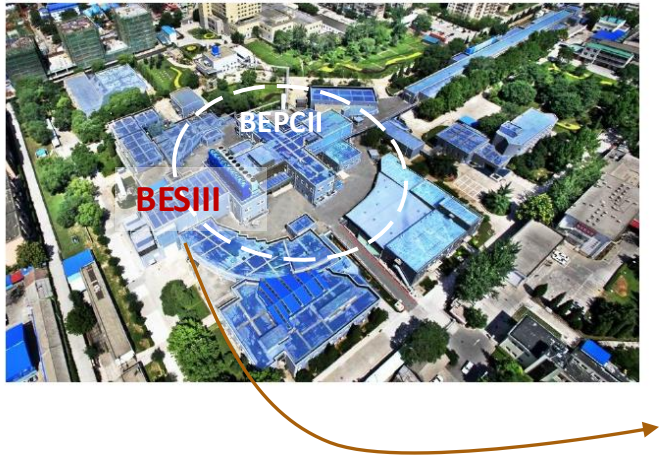
The BESIII Experiment



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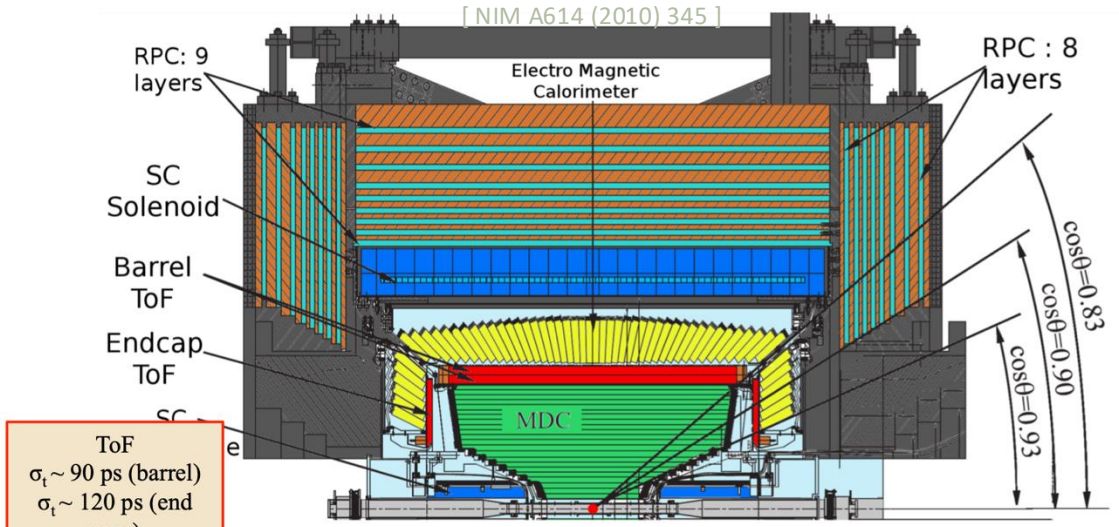


ToF
$\sigma_t \sim 90$ ps (barrel)
$\sigma_t \sim 120$ ps (end caps)

Drift Chamber
$\sigma_{r\phi} \sim 130$ μm (single wire)
$\sigma_{p_t}/p_t \sim 0.5$ % @ 1 GeV

Electromagnetic CsI(Tl) Calorimeter
$\sigma_E/E < 2.5\%$ @ 1 GeV (barrel)
$\sigma_E/E < 5\%$ @ 1 GeV (end caps)
$\sigma_{xy} \sim (6 \text{ mm})/E^{1/2}$ @ 1 GeV

RPC Muon Detector
$\Delta\Omega/4\pi = 93\%$

Located at the BEPCII collider (Beijing, China)

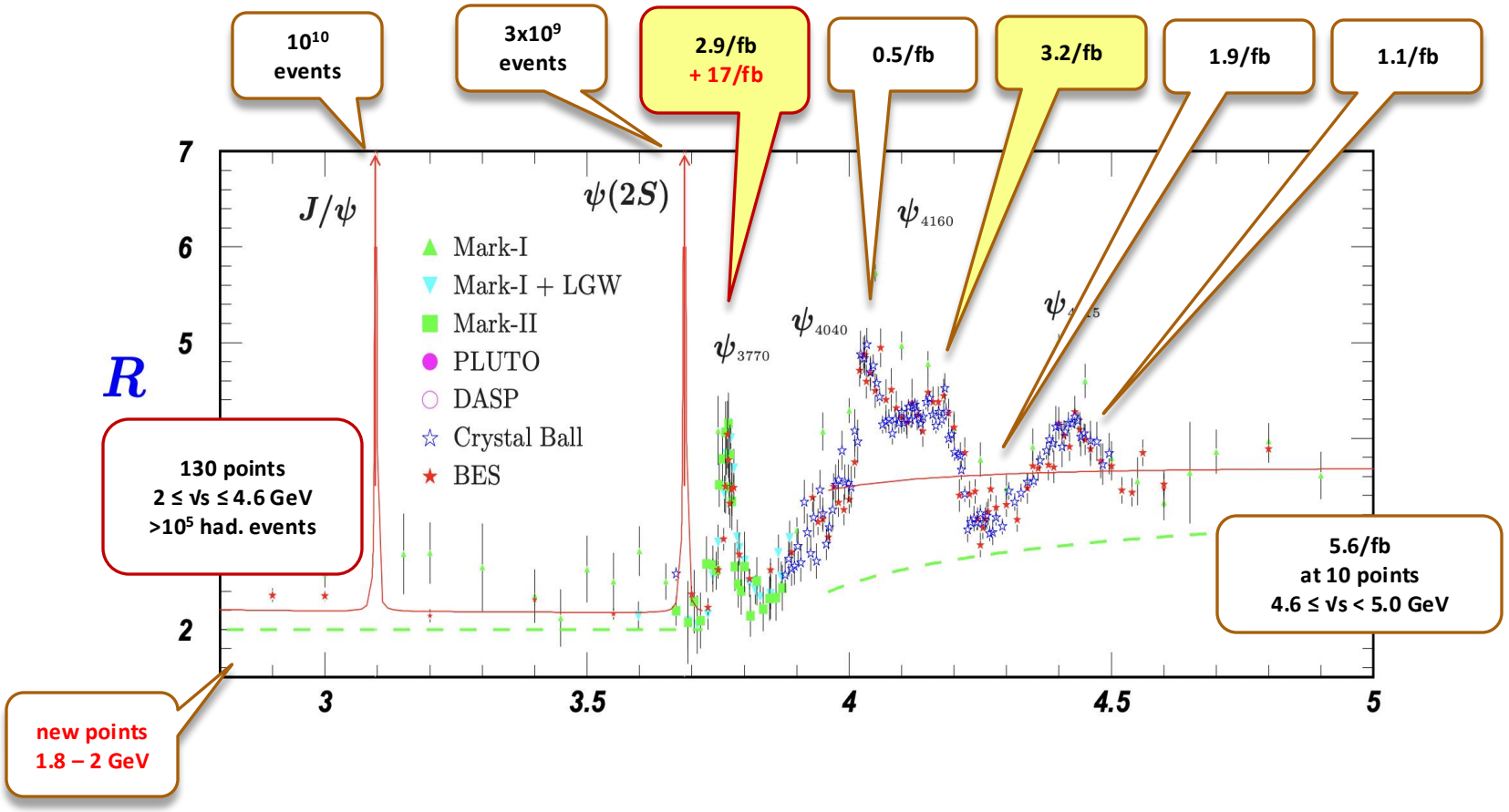
Symmetric e^+e^- beams

ECM between 2-5 GeV

Maximum luminosity: 1 nb^{-1}/s

93% coverage of the solid angle

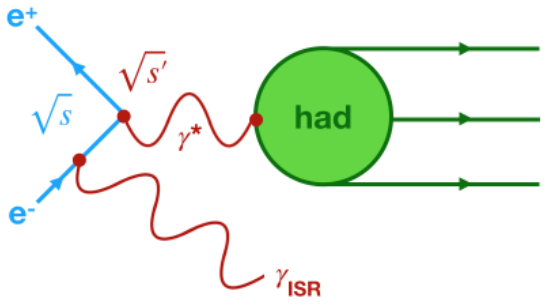
BESIII Contributions to HVP

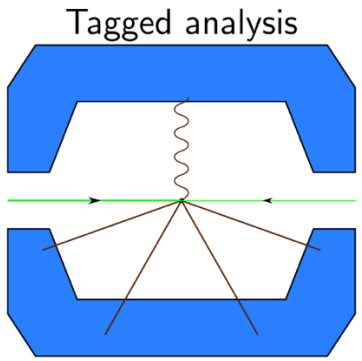


World largest τ-charm dataset in e^+e^- annihilation …

… and still growing

Measurement Strategy: Old and New





- Employ initial state radiation to access relevant energy range
- Radiated photon at large angle – kinematic threshold
- Two charged tracks, identified as pions (NN), originating from IP

Published: [Phys.Lett.B753 (2016) 629]

- Detect ISR photon
- 4C Kinematic Fit (ππγ)
- Phokhara

New:

- Do not look for ISR photon
- 1C Kinematic Fit (ππγ)
- Phokhara, Babayaga@NNLO(?)

Uncertainty from the Generator

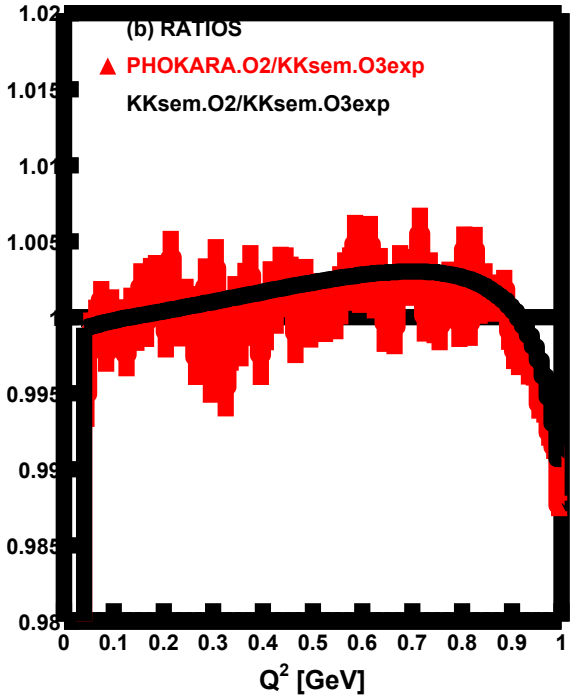
- Phokhara theoretical uncertainty determined in comparison with KKMC: 0.5%
- But fully inclusive comparison, what about selection requirements?

➢ Compare Phokhara and KKMC in the actual analysis.

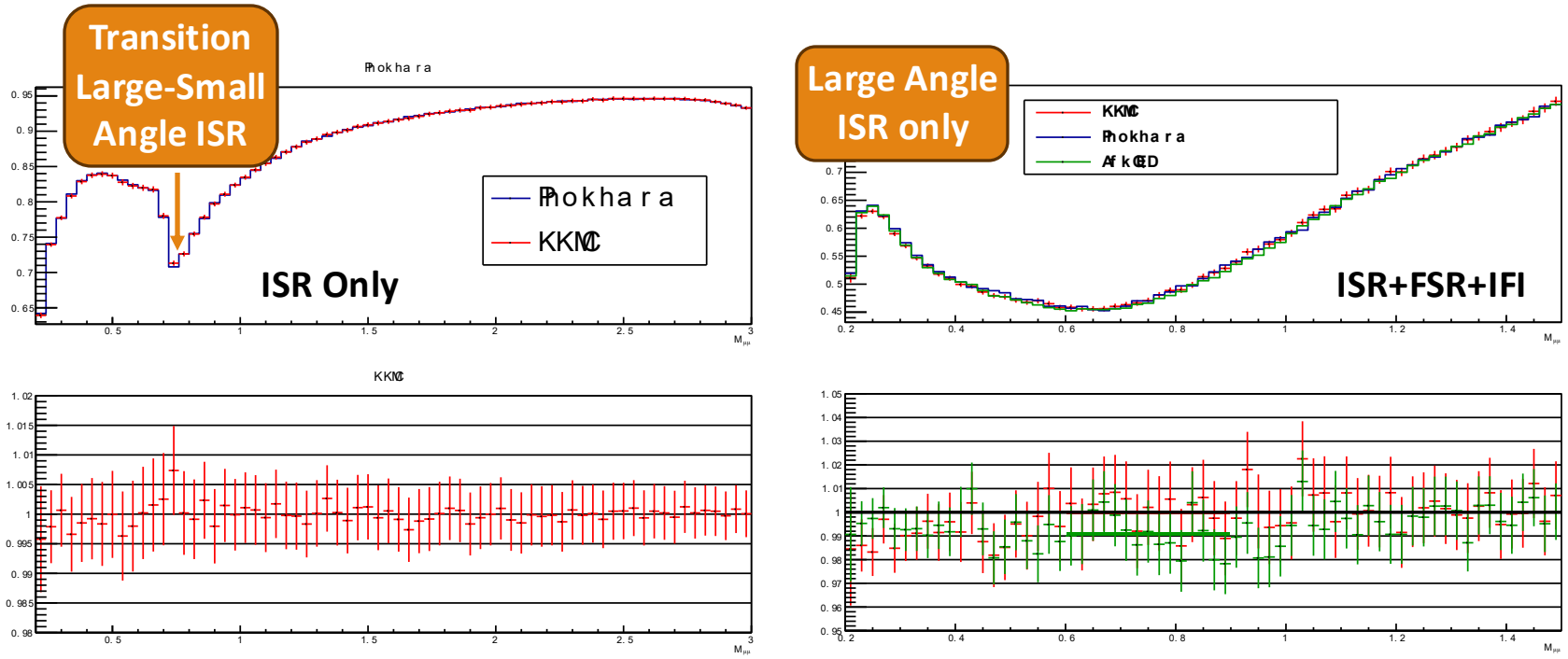
- Inclusive cross section matches:

➢ Only differences in selection efficiency relevant

Study on muons, while waiting for pion MC

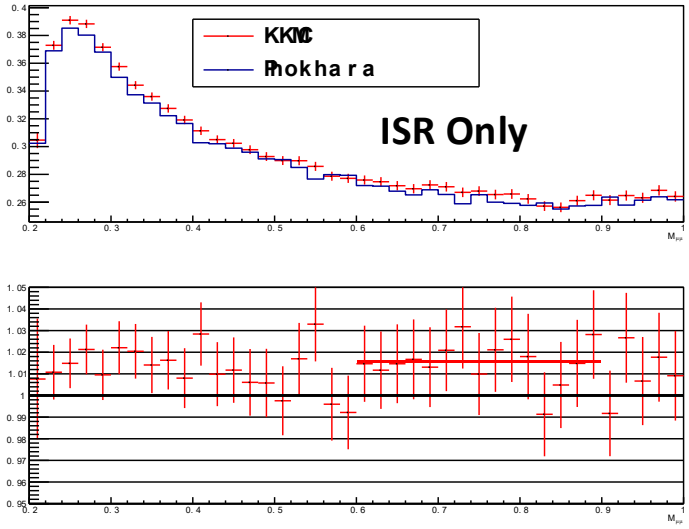


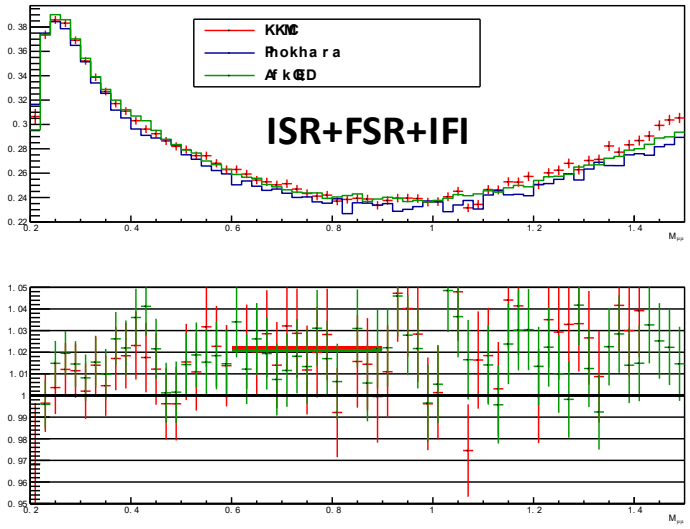
(Tracks) Geometrical Selection



- Agreement better than 0.5% with KKMC
- Small deviation (1%) at lower energies (< 0.6 GeV), add. radiation?
- AfkQED starts deviating (1%) already at 1 GeV

Introduce Kinematic Fit: 4C

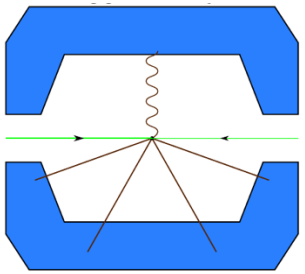




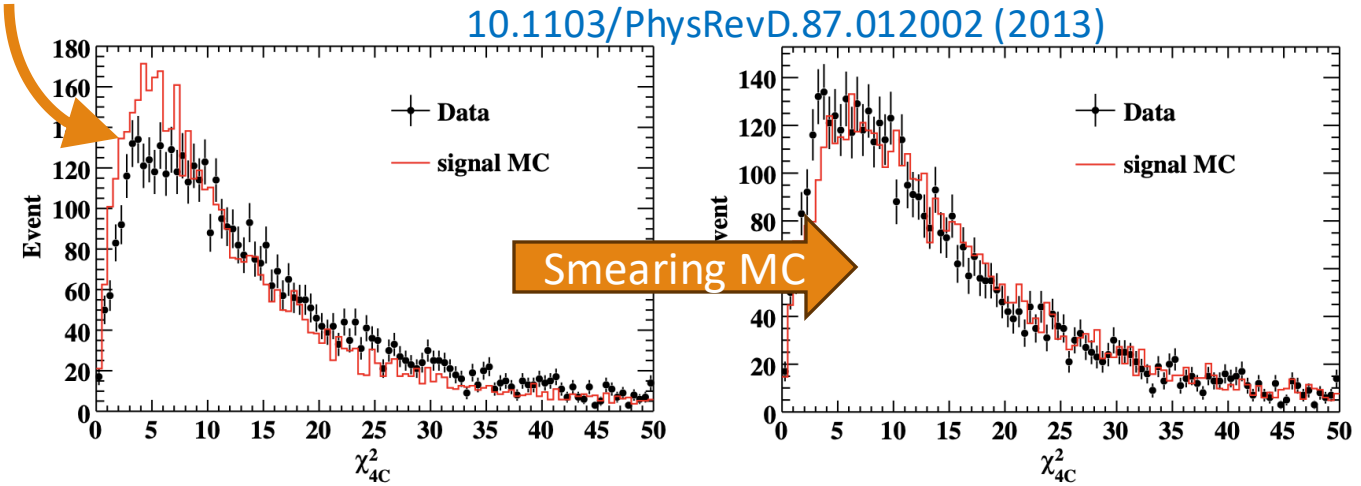
- Clear discrepancy in both ISR only and full radiative configuration
- Agreement between KKMC and AfkQED
  - Is this mitigated by analysis procedure? **Photon detection efficiency**

Photon Detection Efficiency

- Small differences between detector response in data and MC expected
- Correction/calibration factor to take this into account
- In 4C kinematic fit two components:
  - Photon detection efficiency
  - Track & photon energy resolution → χ^2



10.1103/PhysRevD.87.012002 (2013)



- Use control sample to correct for the difference

Photon Detection Efficiency

Using radiative ee → μμ events:

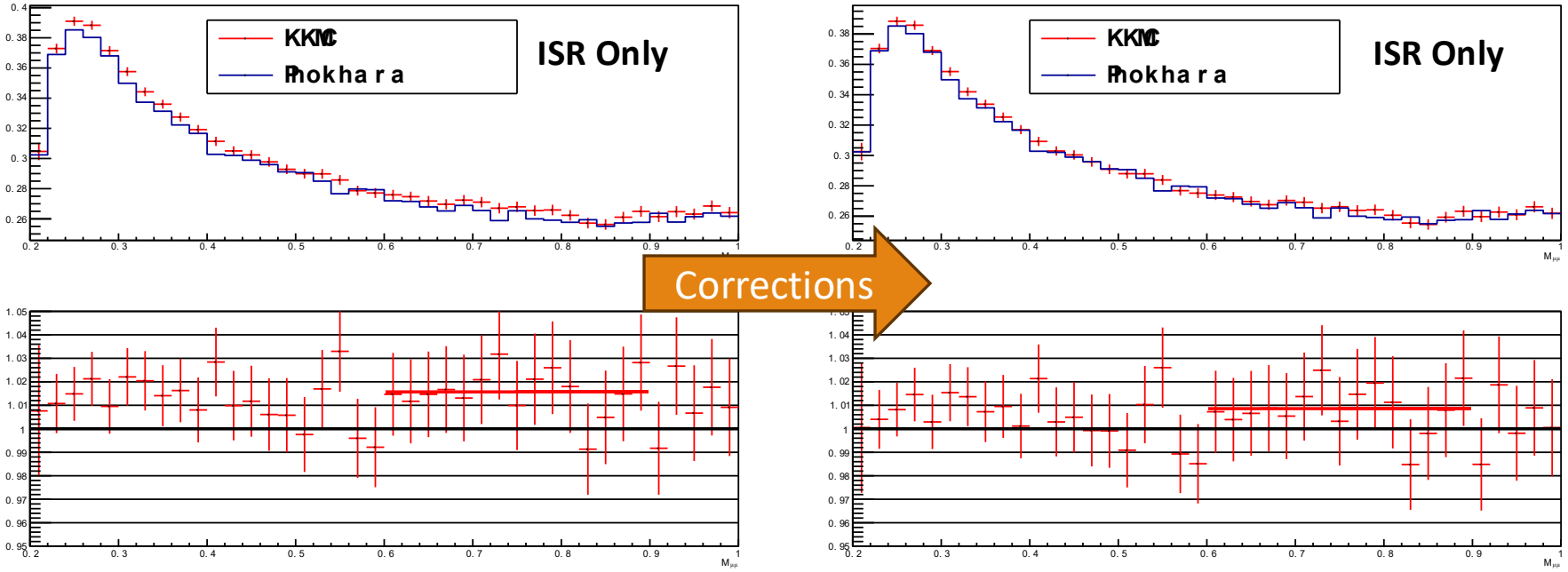
- Perform 1C Kinematic fit (photon momentum prediction, $\chi^2<10$)
- Look for a photon closing the kinematics (4C Kinematic fit)
- Determine efficiency (and relative corrections) for data and MC in bins of energy and polar angle

Such procedure corrects for differences in:

- detection efficiency
- resolution
- **missing NNLO contributions, as long as accepted by 1C**

Test using KKMC/AfkQED as data and correcting Phokhara

Impact of Correction

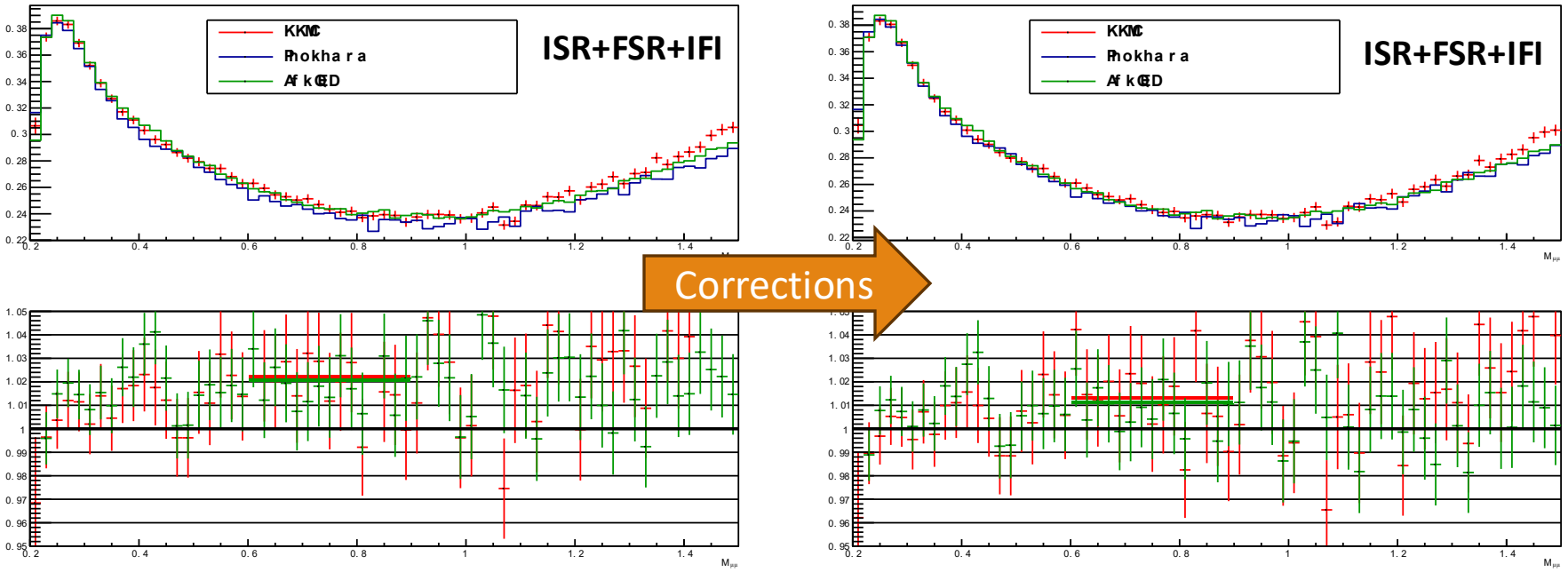


Corrections have an impact on the agreement!

Discrepancy reduced from 1.5% to 1%

- 1C Fit leads to about 1% of higher order contributions to be lost

Impact of Correction



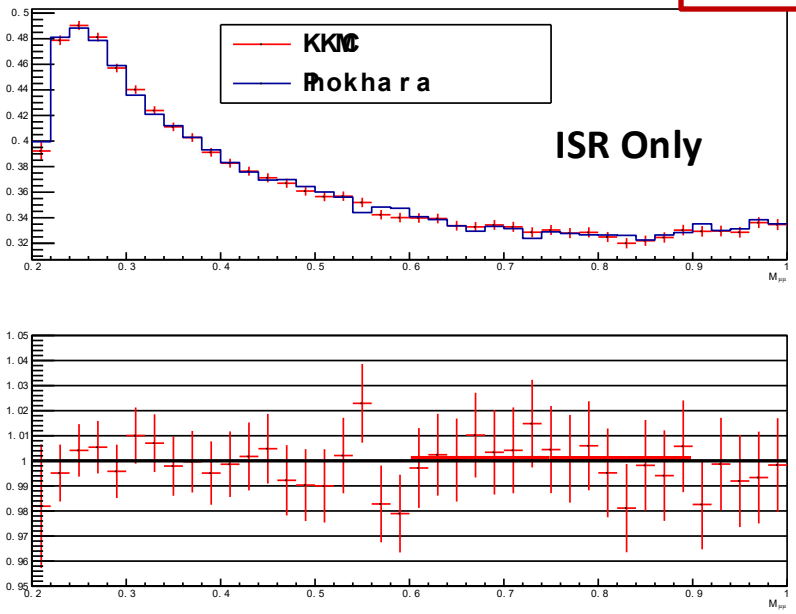
Corrections have an impact on the agreement!

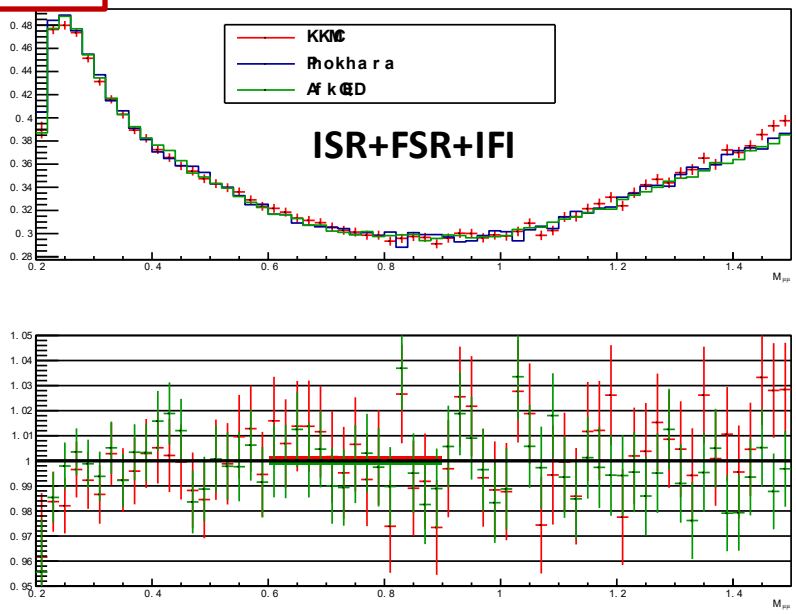
Discrepancy reduced from 2% to 1%

- Still 1% of higher order contributions lost by kinematic fit

Reducing Constraints: 1C Fit

20 < θγ < 160





Reduce the sensitivity to additional radiation (new measurement)

Looser χ^2 cut with respect to photon efficiency (40 vs 10)

- **Good agreement** between Phokhara, KKMC, and AfkQED (at **0.1%**)

Allow for cross check and determination of eventual bias of published result

Conclusion

- **First measurement** of the pion FF by **BESIII** published in 2015
- Claimed **accuracy: 0.9%**
- Investigation of radiative corrections impact on going
- First comparisons between Phokhara, KKMC, and AfkQED suggest **O(1%) bias** may be introduced by the **4C Kinematic Fit**
- **New analysis** on going
  - **First result** based on about **6 fb^{-1}** of data **aiming at 0.7% accuracy** (end of 2025)
  - **Final measurement** based on 20 fb^{-1} **with 0.5% precision** (normalization to muons)
- Looser constraint on kinematics (**1C Kinematic Fit**)
- **No impact** expected from **radiative corrections**!

➢ **Looking forward to MC generator advancements**: Babayaga@(N)NLO, Phokhara(@NNLO), …