Status of Radio MonteCarLow and Strong2020 activities

G. Venanzoni
INFN-Pisa

Radio MonteCarLow: Working Group on Radiative Corrections and MC Generators for Low Energies

- An informal room and a valuable platform to exchange ideas
- Meetings with theorists and experimentalists sitting together.
- First meeting in Oct 2006. 20 meetings since then. More than 60 participants from more than 10 different countries. Last meeting on March 2019
- 2 WG coordinators (H. Czyz, G. Venanzoni)
- 7 Subgroups
- A first report in 2010.

Web page:

http://www.lnf.infn.it/wg/sighad/

www.lnf.infn.it/wg/sighad/

Working Group on Rad. Corrections and MC Generators for Low Energies

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NEW Meetings

Monte Carlo Codes

Comparisons between Generators and num. Codes

Participants

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Working Group on Rad. Corrections and MC Generators for Low Energies

The aim of this Working Group is to bring together theorists and experimentalists in order to discuss the current status of radiative corrections and Monte Carlo generators at low energies. These radiative corrections and MC generators are crucial for the measurement of the R-ratio (both with ISR and energy scan), as well as the determination of luminosity.

The twentieth meeting took place at the Budker Institute of Nuclear Physics in Novosibirsk on Saturday March 2 2019 as satellite of the PHIPSI19 Workshop.

The nineteenth meeting took place in Mainz in the Institute for Nuclear Physics of Mainz on Friday 30 June 2017 as satellite of the PHIPSI17 Workshop.

The eighteenth meeting took place in Frascati, on May 19/20 2016.

The seventeenth meeting took place in Frascati, on April 20/21 2015.

The sixteenth meeting took place in Frascati, on November 18/19 2014.

The fifteenth meeting took place in Mainz, on April 11 2014.

The fourteenth meeting took place in Frascati, on September 13 2013, as a satellite meeting of the PHIPSI13 conference in Rome.

Radio MonteCarlow WG page: www.lnf.infn.it/wg/sighad

People involved

Not updated list

Aachen: Actis, Czakon
Beijing: Shen, Wang, Yuan, Zhang
Berlin: Jegerlehner
Bologna: Caffo, Remiddi
CERN: Beltrame, Mastrolia
Cracov: Grzelińska, Jadach, Przedzinski, Wąs
Dubna: Arbuzov, Kuraev
Edmonton: Penin
Frascati: Isidori, Pacetti, Pancheri, Shekhovtsova,Venanzoni
Freiburg: van der Bij
Karlsruhe: Kluge, Kühn,
Katowice: Czyż, Gluza, Kołodziej
Kharkov: Korchin
Mainz: Denig, Ferroglia, Hafner, Mueller
Moscow: Pakhlova
Novosibirsk: Cherepanov, Eidelman, Fedotovich, Sibidanov, Solodov
Palaiseau: Kalinowski
Padova: Passera
Parma: Trentadue
Pavia: Montagna, Nicrosini, Piccinini
Rome: Baldini, Bini, Greco, Nguyen
Southampton: Carloni-Calame
Valencia: Rodrigo, Roig
Wuppertal: Worek
Zeuthen: Riemann

The Subjects covered:

- Monte Carlo generators for Luminosity
- Monte Carlo generators for e+e- into hadrons and leptons
- Monte Carlo generators for e+e- into hadrons and leptons plus photon (ISR)
- Monte Carlo generators for τ production and decays
- Hadronic Vacuum Polarization, $\Delta\alpha_{em}$(Z0) and $(g-2)_{\mu}$
- Gamma-gamma physics
- FSR models and Transition Form Factors

Each of them has 2 convenors

Why we need e^+e^- into hadrons data (R(s))

$$a_\mu^{\text{had,LO}} = \frac{\alpha^2}{3\pi^2}\int_{4m_\pi^2}^{\infty}\frac{ds}{s}\,K(s)\;R(s)$$

$$R(s) = \frac{\sigma(e^+e^-\to hadrons)}{\sigma_{\text{point}}}$$

One has to measure :

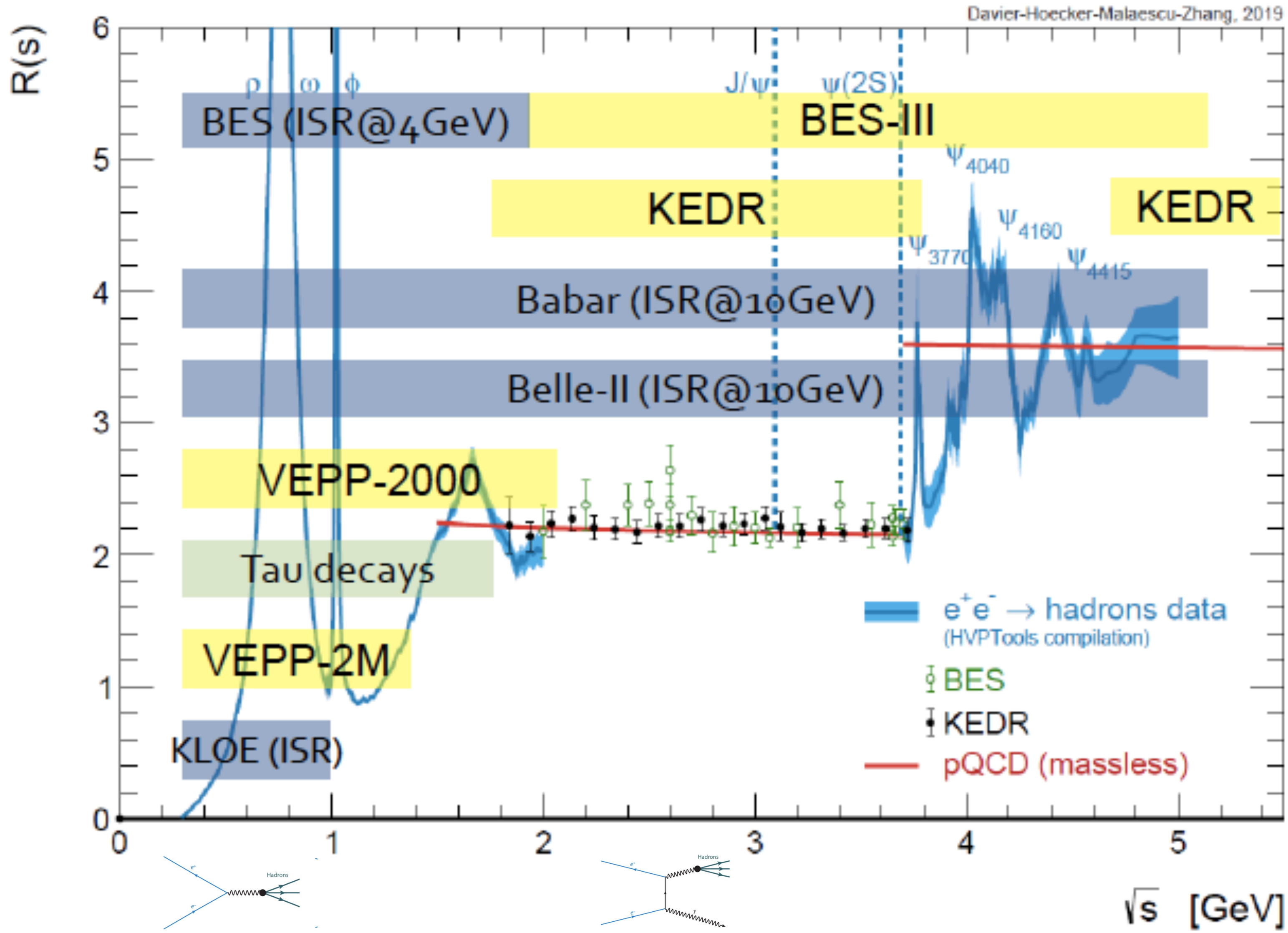
$$\sigma(e^+e^- \to hadrons)$$

From the White Paper (Physics Reports 887 (2020) 1):

$$a_\mu^{\text{had}}(LO) = 693.1(4.0)\times 10^{-10}$$

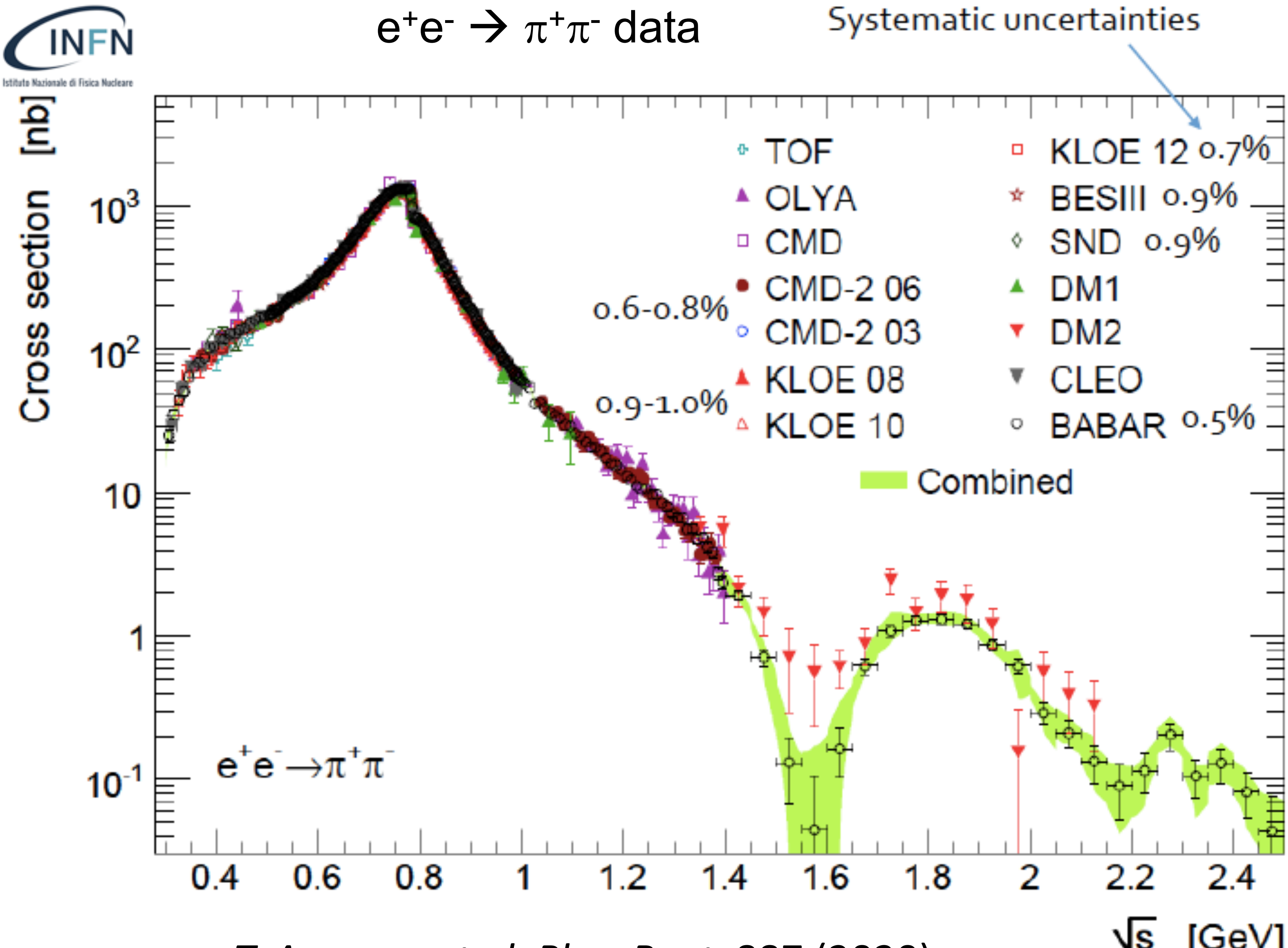
$$\delta a_\mu^{HLO}/a_\mu^{HLO}=0.6\%$$

e^+e^- into hadrons data



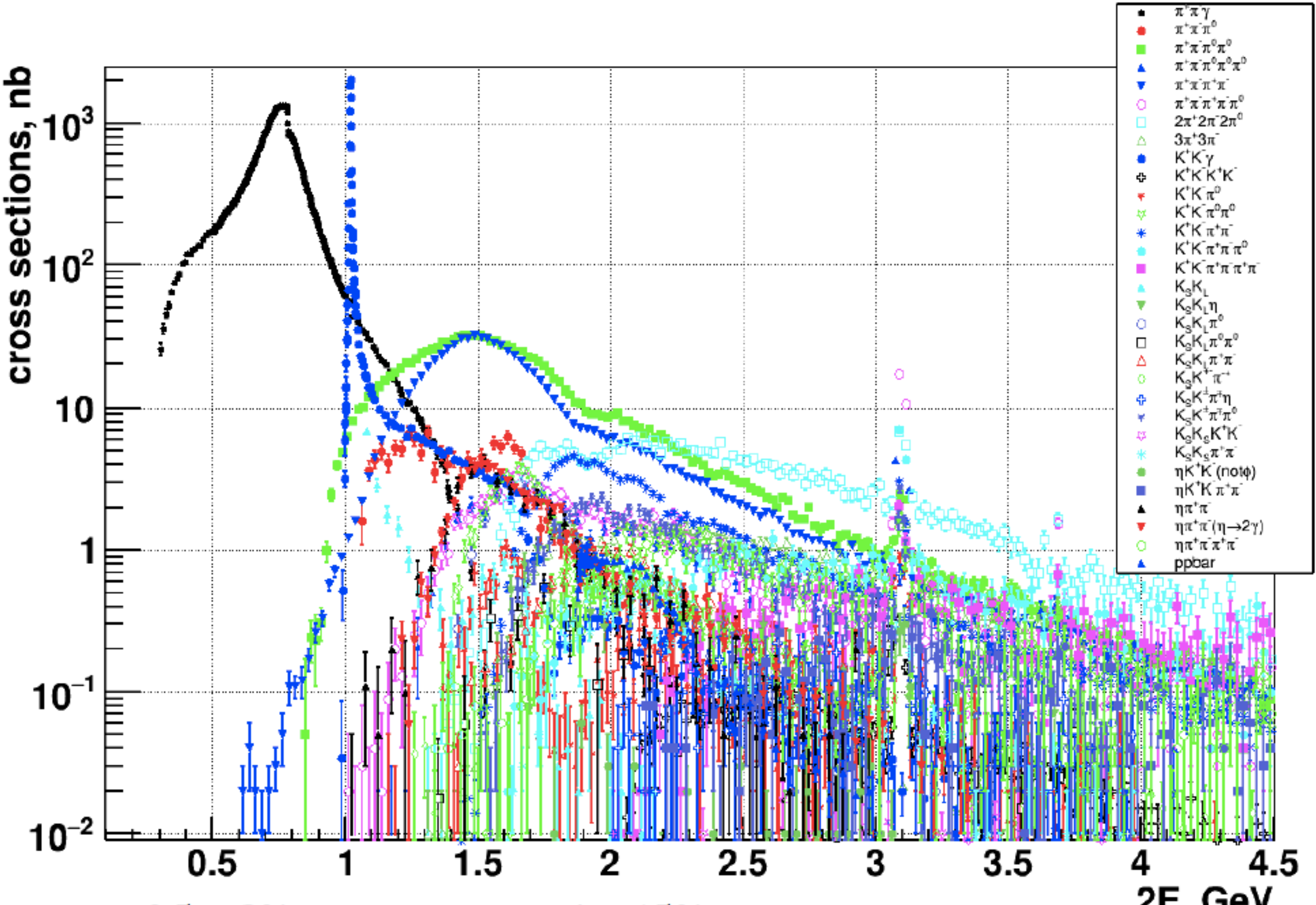
Energy scan | ISR | Tau decays

$e^+e^- \to \pi^+\pi^-$ data



T. Aoyama et al, Phys.Rept. 887 (2020)

BaBar ISR data



$0.5 - 2\%$ syst.error $\qquad 4 - 15\%$ syst.error

Why we need Radiative Corrections

"Visible" cross section
$\sigma(e^+e^-(\gamma) \to X(\gamma))$

Here we correct for all detector effects

Adjust for radiative corrections (ISR, FSR)
$\sigma(e^+e^- \to X)$

This one is used to get parameters of the resonances (mass, width,…)

Adjust for vacuum polarization and return back FSR
$\sigma^0(e^+e^- \to X(\gamma))$

This one is used in the a_μ integral

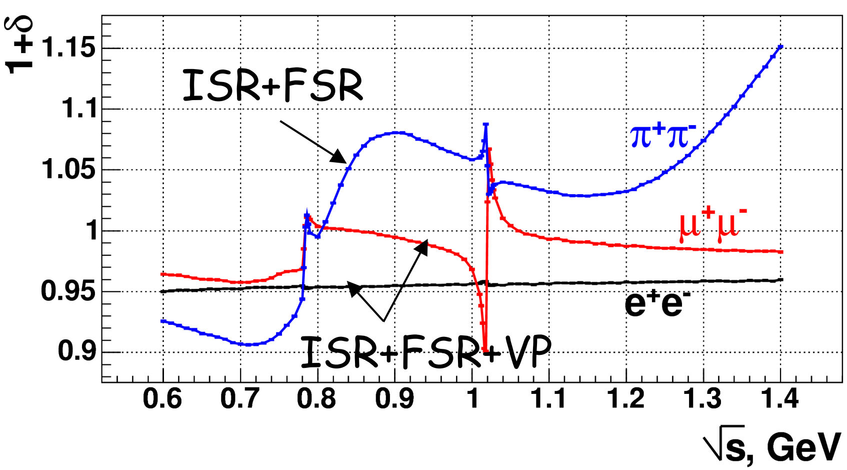
$$a_\mu^{\mathrm{had,LO}} = \frac{\alpha^2}{3\pi^2} \int_{4m_\pi^2}^{\infty} \frac{ds}{s}\, K(s)\, R(s)$$

Radiative corrections for **energy scan**:

All modes except 2π

$$\sigma\left(e^+e^- \to H\right) = \frac{N_H - N_{bg}}{L \cdot \varepsilon \cdot (1+\delta)}$$

- Luminosity L is measured using Bhabha scattering at large angles
- Efficiency ε is calculated via Monte Carlo + corrections for imperfect detector
- Radiative correction δ accounts for ISR effects only



2π

$$\left|F_\pi\right|^2 = \frac{N_{2\pi}}{N_{ee}} \cdot \frac{\sigma_{ee} \cdot (1+\delta_{ee})}{\sigma_{2\pi}(\text{point-like } \pi) \cdot (1+\delta_{2\pi})}$$

- Ratio N(2π)/N(ee) is measured directly $\Rightarrow$ detector inefficiencies are (partially) cancelled out
- Virtually no background
- Analysis does rely mostly on data
- Radiative corrections account for ISR and FSR effects
- Formfactor is measured to better precision than L (true VEPP2M; in VEPP2000 ~same precision)

Radiative corrections for ISR (KLOE)

Radiator-Function $H(s,s_p)$ (ISR):

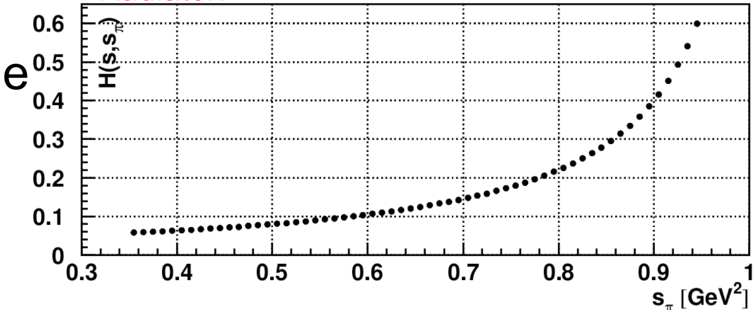
- ISR-Process calculated at NLO-level *PHOKHARA* generator
(H.Czyż, A.Grzelińska, J.H.Kühn, G.Rodrigo, EPJC27,2003)

← It cancels in the ratio to μμγ

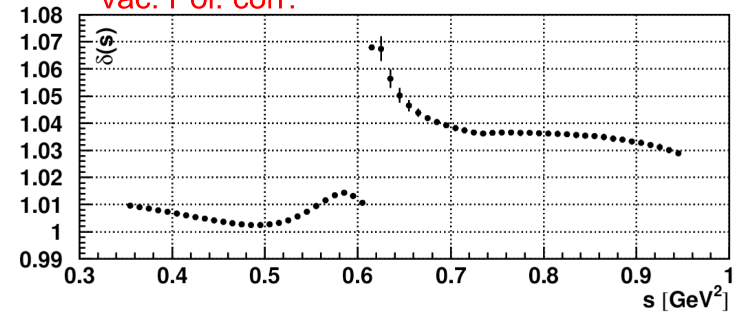
Precision: *0.5%*

$$s \cdot \frac{d\sigma_{\pi\pi\gamma}}{ds_\pi} = \sigma_{\pi\pi}(s_\pi) \times H(s,s_\pi)$$

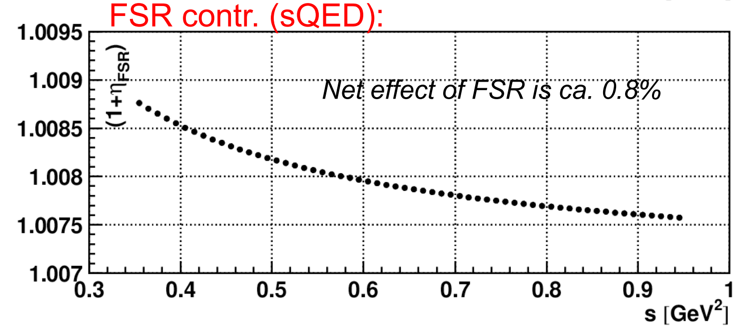
Radiator:



Vac. Pol. corr:



FSR contr. (sQED):



Radiative Corrections:

i) Bare Cross Section

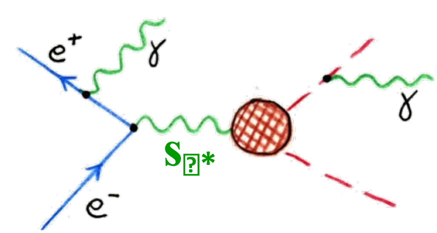
divide by Vacuum Polarisation $d(s)=(a(s)/a(0))^2$

ii) FSR

Cross section s_{pp} must be incl. for FSR for use in the dispersion integral of a_m

FSR corrections have to be taken into account in the efficiency eval. (Acceptance, M_{Trk}) and in the mapping $s_\pi \rightarrow s_{\gamma*}$

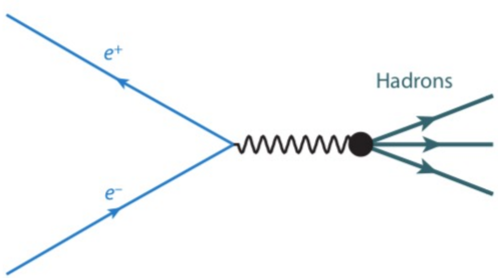
(H.Czyż, A.Grzelińska, J.H.Kühn, G.Rodrigo, EPJC33,2004)



$s_{\gamma*} > s_p$

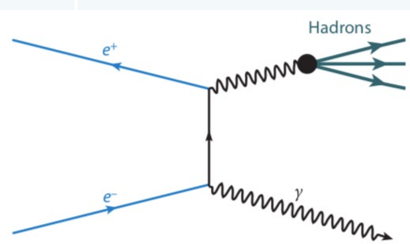
MC generators for exclusive channels (exact NLO + Higher Order terms in some approx)

MC generator	Channel	Precision	Comment
MCGPJ (VEPP-2M, VEPP-2000)	$e^+e^- \rightarrow e^+e^-, \mu^+\mu^-, \pi^+\pi^-, \ldots$	0.2%	photon jets along all particles (collinear Structure function) with exact NLO matrix elements
BabaYaga@NLO (KLOE, BaBar, BESIII)	$e^+e^- \rightarrow e^+e^-, \mu^+\mu^-, \gamma\gamma$	0.1%	QED Parton Shower approach with exact NLO matrix elements
BHWIDE (LEP)	$e^+e^- \rightarrow e^+e^-$	(0.1%?)	Yennie-Frautschi-Suura (YFS) exponentiation method with exact NLO matrix elements



MC generators for ISR
(from approximate to exact NLO)

MC generator	Channel	Precision	Comment
EVA (KLOE)	$e^+e^- \to \pi^+\pi^-\gamma$	O(%)	Tagged photon ISR at LO + Structure Function FSR: point-like pions
AFKQED (BaBar)	$e^+e^- \to \pi^+\pi^-\gamma$, …	depends on the event selection (can be as good as Phokhara)	ISR at LO +Structure Function
PHOKHARA (KLOE, BaBar BESIII)	$e^+e^- \to \pi^+\pi^-\gamma$, $\mu^+\mu^-\gamma$, $4\pi\gamma$, …	0.5%	ISR and FSR(sQED+Form Factor) at NLO
KKMC	$e^+e^- \to f^+f^-(n)\gamma$	High accuracy only for muon pairs	YFS exponentiation for soft photons + hard part and sub-leading terms in some approximation



"Tuned" comparisons are essential!

Theoretical accuracies of these generators were estimated, whenever possible, by evaluating missing higher-order contributions. From this point of view, the great progress in the calculation of two-loop corrections to the Bhabha scattering cross section was essential to establish the high theoretical accuracy of the existing generators for the luminosity measurement. However, usually only analytical or semi-analytical estimates of missing terms exist which don't take into account realistic experimental cuts. In addition, MC event generators include different parameterisations for the VP which affect the prediction (and the precision) of the cross sections and also the RC are usually implemented differently.

BabaYaga and its theoretical accuracy

Carlo M. Carloni Calame

INFN, Sezione di Pavia

Working Group on Radiative corrections and generators for low energy hadronic cross section and luminosity

based on hep-ph/0607181 (accepted by **NPB**)

in collaboration with G. Balossini, G. Montagna, O. Nicrosini, F. Piccinini

Estimate of the theoretical accuracy

- switching off VP, tuned comparisons with independent calculations/approaches (`Labspv`, `Bhwide`)
  - ⋆ $\Delta\sigma/\sigma < 0.03\%$ on cross sections
  - ⋆ up-to-0.5% differences between `BabaYaga` and `Bhwide` in distribution tails
- comparison with existing perturbative 2-loop calculations
  - ⋆ currently available
    1. Penin: complete virtual 2-loop photonic corrections (for $Q^2 \gg m_e^2$) plus real radiation in the soft limit
    2. Bonciani et al.: virtual $N_F = 1$ [only electron in the loops] fermionic contributions plus real radiation in the soft limit
  - ⋆ the photonic and $N_F = 1$ $\mathcal{O}(\alpha^2)$ content of the S+V part in the `BabaYaga` matched formula can be easily extracted. The terms to be directely compared to 1. and 2. can be read out!
  - ⋆ the impact of the missing $\mathcal{O}(\alpha^2)$ S+V corrections can be quantified within realistic setup

Summary of theoretical errors

- for Bhabha cross section, within realistic setup for luminometry, the theoretical errors of the new BabaYaga are summarized

$\|\delta^{err}\|$ (%)	(a)	(b)	(c)	(d)
$\|\delta^{err}_{VP}\|$	0.01	0.00	0.02	0.04
$\|\delta^{err}_{pairs}\|$	0.02	0.03	0.03	0.04
$\|\delta^{err}_{H,H}\|$	0.00	0.00	0.00	0.00
$\|\delta^{err}_{phot+N_f=1}\|$	0.01	0.01	0.00	0.01
$\|\delta^{err}_{SV,H}\|$	0.05	0.05	0.05	0.05
$\|\delta^{err}_{total}\|$	0.09	0.09	0.10	0.14

Table: LABS (a) (c), VLABS (b) (d), 1.02 GeV (a) (b), 10 GeV (c) (d)

MCGPJ

RADIO MONTECARLOW

Higher order QED radiative corrections to Bhabha scattering

Andrej Arbuzov

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia

Talk at the Radio MontecarLow workshop, Frascati, 6–7th April 2009

MCGPJ: A. Arbuzov

Outlook

- The ansatz for the treatment of $\mathcal{O}\left(\alpha^2 L^1\right)$ QED radiative corrections to exclusive observables is described
- The ansatz is suited for MC simulations
- Many processes can be treated in this way
- $\mathcal{O}\left(\alpha^2 L^0\right)$ contributions can be put into the same structure
- MCGPJ can be upgraded
- MC integrator and generator for Bhabha scattering is under development (upgrade of SAMBHA MC)

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Istituto Nazionale di Fisica Nucleare

RADIO MONTECARLow

PHOKHARA MC generator

EVA: $e^+e^- \to \pi^+\pi^-\gamma$

- tagged photon ($\theta_\gamma > \theta_{cut}$)
- ISR at LO + Structure Function
- FSR: point-like pions

[Binner et al.]

$e^+e^- \to 4\pi + \gamma$

- ISR at LO + Structure Function

[Czyż, Kühn,2000]

F. Campanario, H.C., J. Gluza,
A. Grzelińska, M. Gunia, P. Kisza,
J. H. Kühn, E. Nowak-Kubat, T. Riemann,
G. Rodrigo, Sz. Tracz, A. Wapienik,
V. Yundin, D. Zhuridov

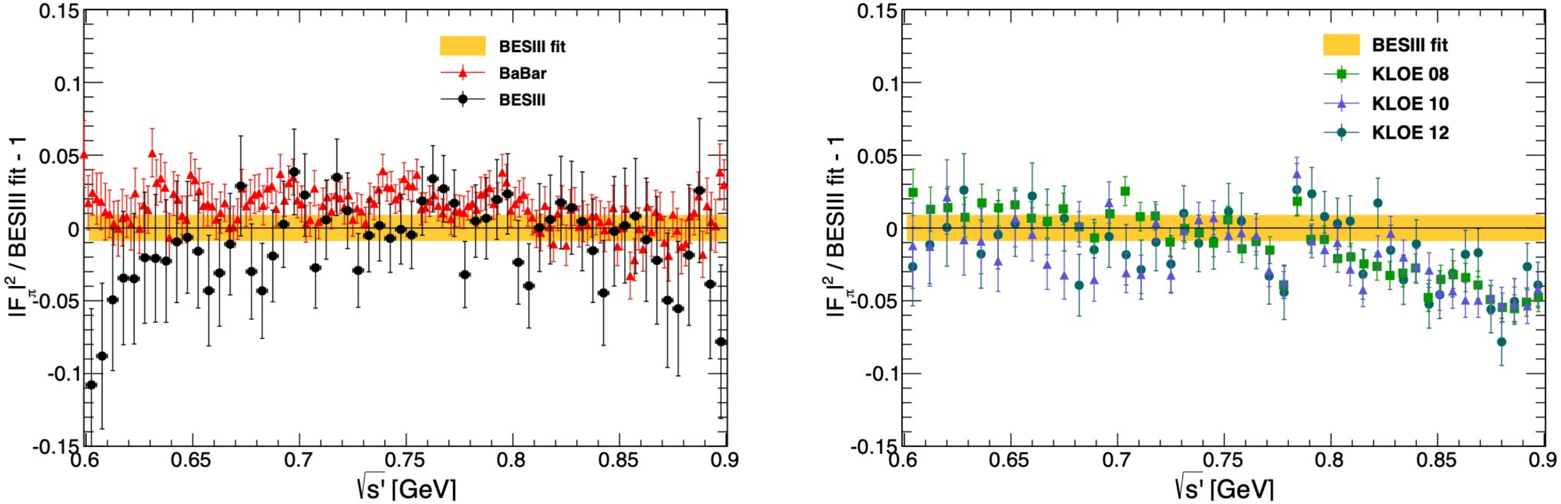
PHOKHARA 10.0: $\pi^+\pi^-, \mu^+\mu^-,$
$4\pi,\ \bar{N}N,\ 3\pi,\ KK, \Lambda\bar{\Lambda},\ P\gamma$
$J/\psi, \psi(2S), \chi_{c1}, \chi_{c2}$

- **ISR at NLO:** virtual corrections to one photon events and two photon emission at tree level

- FSR at NLO: $\pi^+\pi^-$, $\mu^+\mu^-$, K^+K^-, $\bar{p}p$
- tagged or untagged photons
- $e^+e^- \to$ *hadrons* (*muons*) ISR at NNLO
- Modular structure

http://ific.uv.es/~rodrigo/phokhara/

ISR measurements



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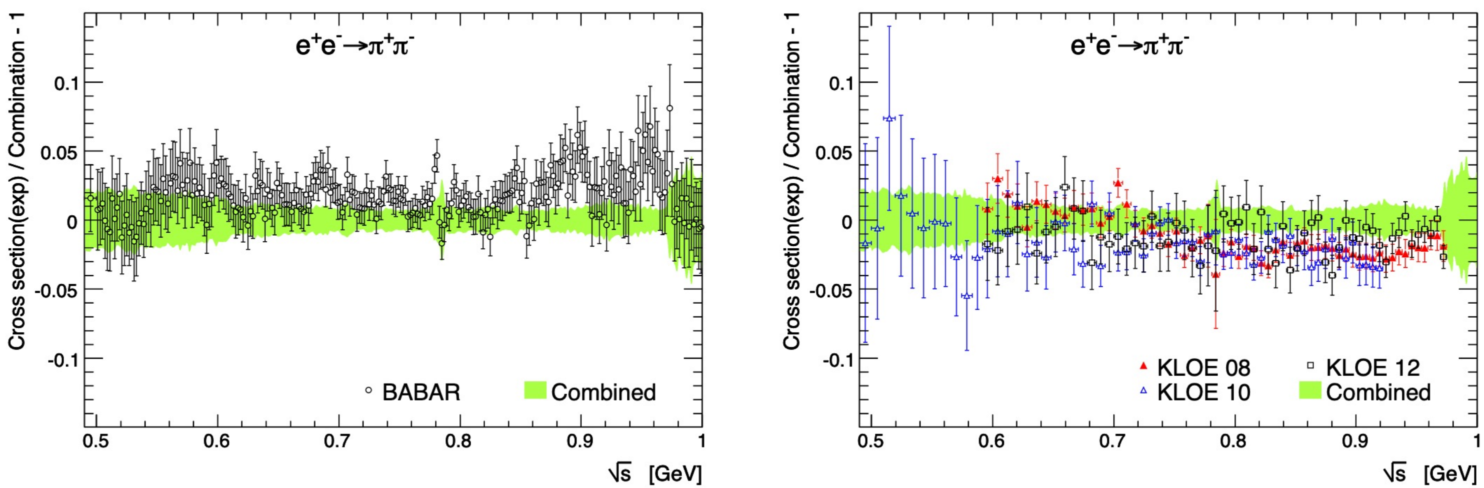
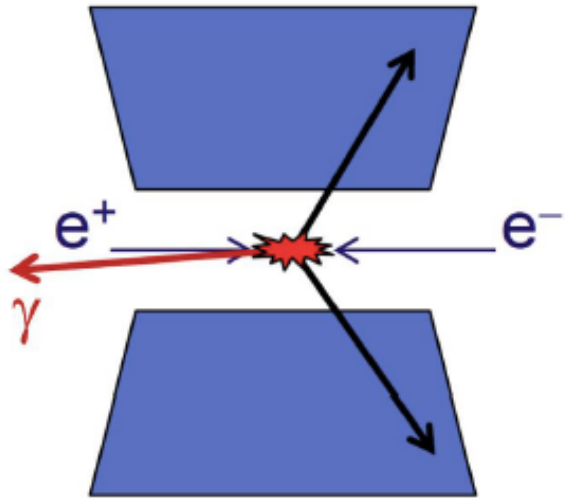
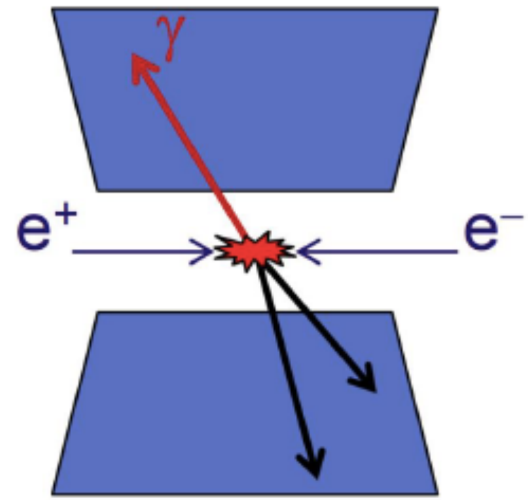


ISR measurements





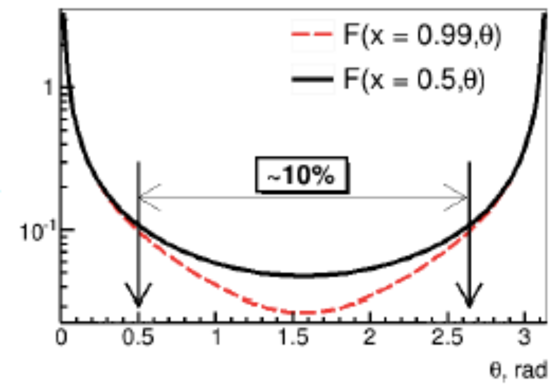
Small angle (untagged) ISR

- ISR photon emitted along initial beam, undetected
- ISR photon is reconstructed from kinematics of the final state

Large angle (tagged) ISR

- ISR photon emitted at large angle and detected

Angular distribution of γ_{ISR}



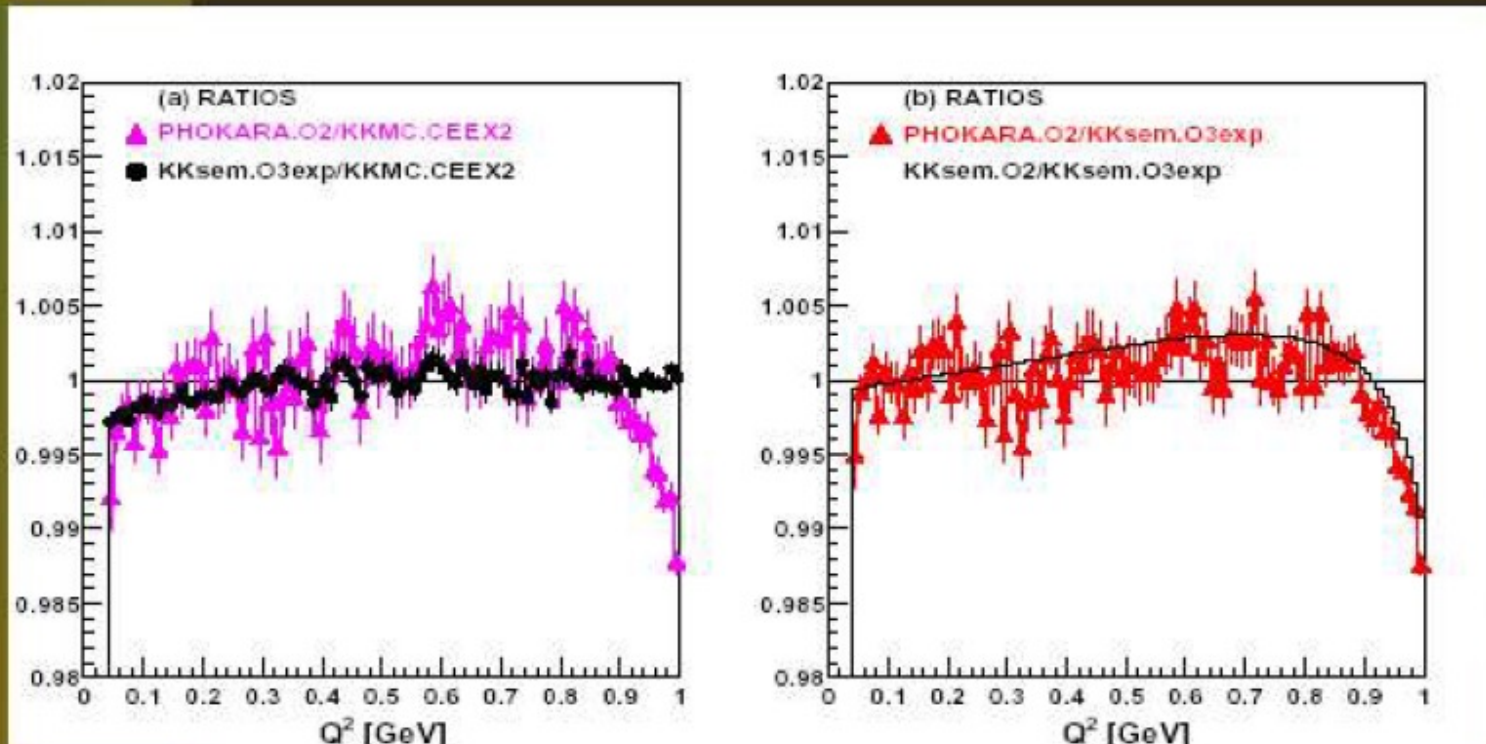
Different ISR approaches

	Tagged ISR	Untagged ISR
Normalization to e^+e^-	KLOE-2010 ($\pi^+\pi^-$) BABAR (most channels)	KLOE-2005 ($\pi^+\pi^-$) KLOE-2008 ($\pi^+\pi^-$) BABAR ($p\bar{p}$)
Normalization to $\mu^+\mu^-(\gamma)$	BABAR ($\pi^+\pi^-$)* BES-III ($\pi^+\pi^-$) CLEO-c ($\pi^+\pi^-$)	KLOE-2012 ($\pi^+\pi^-$)

(I. Logashenko)

PHOKHARA vs KKMC $\mu\mu\gamma$

PHOKHARA included in the game, μ-pairs again



PHOKHARA agrees to within 0.3% with KKMC and KKsem.

Discrepancy at high Q^2 reflects lack of exponentiation in PHOKHARA

Report from RMCWG: a common effort for RC and Monte Carlo tools

Eur. Phys. J. C (2010) 66: 585–686
DOI 10.1140/epjc/s10052-010-1251-4

THE EUROPEAN PHYSICAL JOURNAL C

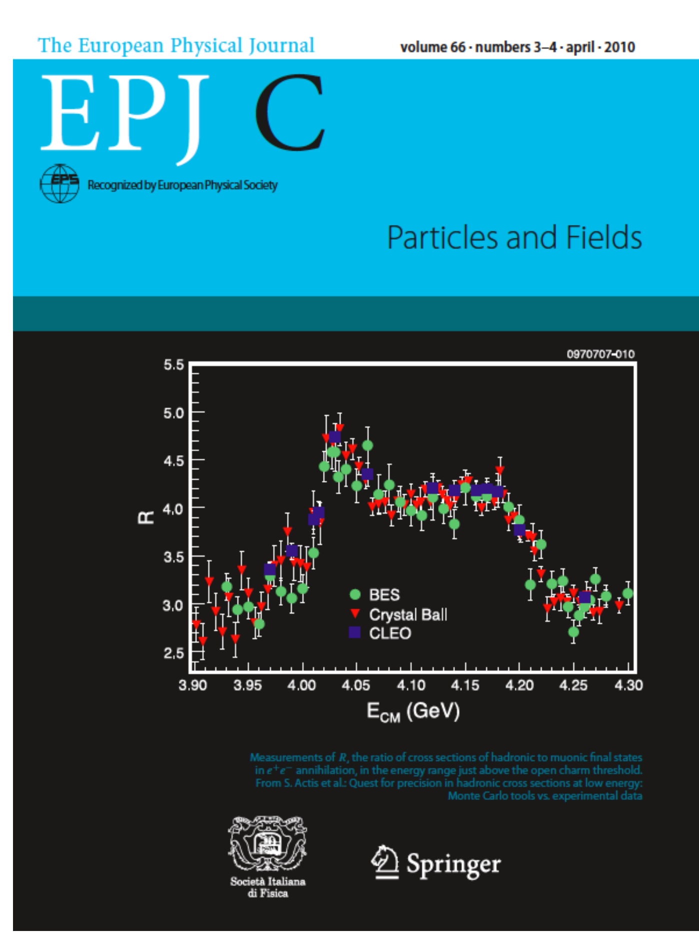
Review

Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data

Working Group on Radiative Corrections and Monte Carlo Generators for Low Energies

S. Actis[38], A. Arbuzov[9,e], G. Balossini[32,33], P. Beltrame[13], C. Bignamini[32,33], R. Bonciani[15], C.M. Carloni Calame[35], V. Cherepanov[25,26], M. Czakon[1], H. Czyż[19,a,f,i], A. Denig[22], S. Eidelman[25,26,g], G.V. Fedotovich[25,26,e], A. Ferroglia[23], J. Gluza[19], A. Grzelińska[8], M. Gunia[19], A. Hafner[22], F. Ignatov[25], S. Jadach[8], F. Jegerlehner[3,19,41], A. Kalinowski[29], W. Kluge[17], A. Korchin[20], J.H. Kühn[18], E.A. Kuraev[9], P. Lukin[25], P. Mastrolia[14], G. Montagna[32,33,b,d], S.E. Müller[22,f], F. Nguyen[34,d], O. Nicrosini[33], D. Nomura[36,h], G. Pakhlova[24], G. Pancheri[11], M. Passera[28], A. Penin[10], F. Piccinini[33], W. Płaczek[7], T. Przedzinski[6], E. Remiddi[4,5], T. Riemann[41], G. Rodrigo[37], P. Roig[27], O. Shekhovtsova[11], C.P. Shen[16], A.L. Sibidanov[25], T. Teubner[21,h], L. Trentadue[30,31], G. Venanzoni[11,c,i], J.J. van der Bij[12], P. Wang[2], B.F.L. Ward[39], Z. Was[8,g], M. Worek[40,19], C.Z. Yuan[2]

Eur. Phys. J. C. Volume 66, Issue 3 (2010), Page 585



Moving forward…

From the White Paper (Physics Reports 887 (2020) 1):

$$a_\mu^{\mathrm{had}}(LO) = 693.1(4.0) \times 10^{-10}$$

The expected final precision of the Fermilab measurement

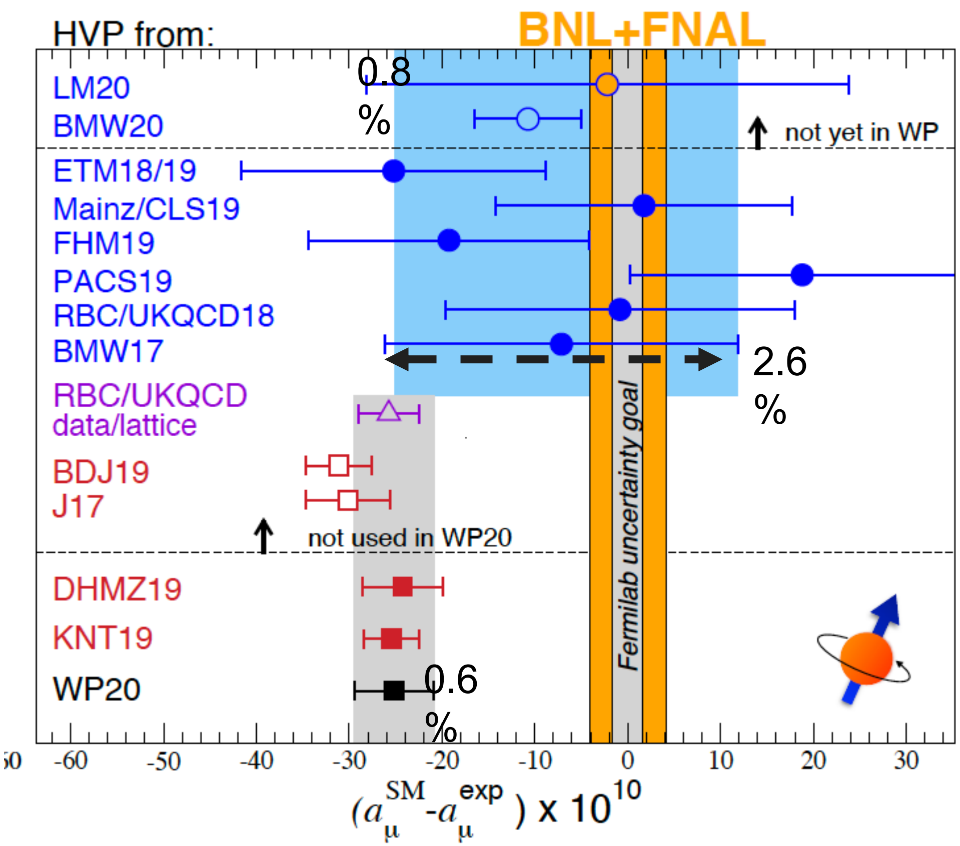
$$\Delta a_\mu = 1.6 \times 10^{-10}$$

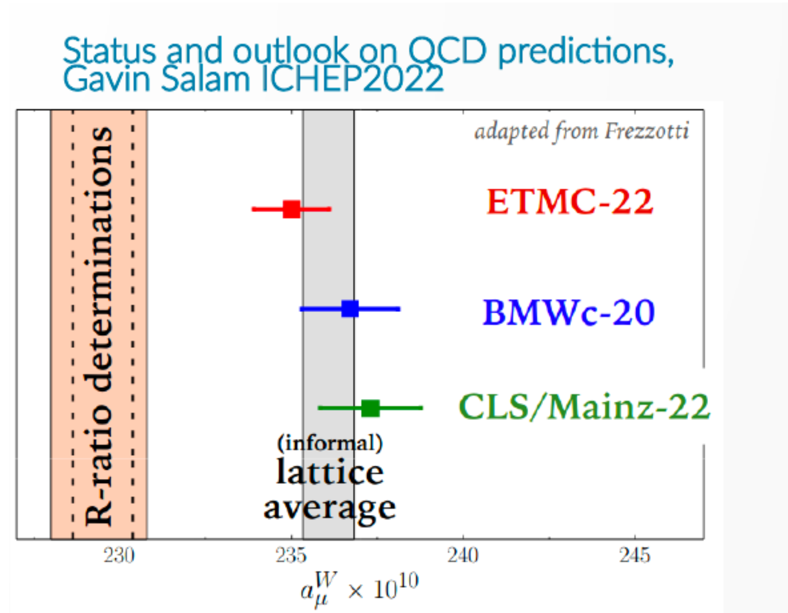
We need to know $R(s)$ to 0.23% to match Fermilab precision

Now the hadronic contribution is known to 0.57%

Is this doable?

Understanding Lattice vs e+e- tension





Also Fermilab Lattice/HPQCD/MILC shows consistent results (2207.04765)

Can (missing) RC in e+e- data play a role?

Moving forward…

- A lot of new data/measurements from VEPP-2000, BaBar, BelleII, BESIII with better quality and refined systematic errors
- Radiative corrections and MC generators (R scan and ISR) should aim at 0.1% uncertainty → NNLO (help from MUonE/Fcc-ee community?) EPJC80 (2020) 6, 591
- Test of FSR model (BaBar using charge asymmetry and KLOE using f.b. asymmetry; tests undergoing at VEP2000)

- Radio MC activity is still very important!!

(Virtual) meeting: 24-26 November 2021

https://agenda.infn.it/event/28089

STRONG 2020 Virtual Workshop on "Spacelike and Timelike determination of the Hadronic Leading Order contribution to the Muon g-2"

24-26 November 2021
Europe/Rome timezone

- Overview
- Scientific Programme
- Call for Abstracts
- Timetable
- Book of Abstracts
- Registration
- Participant List
- Program committee
- Proceedings

This is the first workshop of STRONG2020 WP21: JRA3-PRECISION TESTS OF THE STANDARD MODEL". It will be devoted to reviewing the WG activity and in more general to discuss the status of HVP spacelike and timelike determinations. The format will be online from Wednesday November 24 to Friday 26, with zoom sessions, 3 hours (2:00-5:00pm CET) each day. As a deliverable of this workshop we expect a book of abstracts to be submitted to ArXiv.

Starts 24 Nov 2021, 14:00
Ends 26 Nov 2021, 17:00
Europe/Rome

There are no materials yet.

>100 participants; very reach agenda!

Proceedings at arXiv:2201.12102 [hep-ph]

(Virtual) meeting: 24-26 November 2021

Review of the e^+e^- generators

MCGPJ and ReneSANCe MC event generators: status and perspectives	*Andrej Arbuzov*	14:00 - 14:15
BABAYAGA MC generator: status and prospects	*Carlo Michel Carloni Calame*	14:15 - 14:30
PHOKHARA MC generator: status and prospects	*Henryk Czyz*	14:30 - 14:45
KKMCee/BHLUMI/BHWIDE MC generators: status and prospects	*Staszek Jadach*	14:45 - 15:00
KKMC: new tau decays, New Physics vector/scalar resonances	*Zbigniew Andrzej Was*	15:00 - 15:15
Coffee Break		15:15 - 15:25
Discrepancies between current MC generators	*Fedor Ignatov*	15:25 - 15:40
Radiative corrections to e+e- -> pi+pi- based on a dispersive approach	*Gilberto Colangelo*	15:40 - 16:00
Perspectives from theory on $e^+e^-\to 2\pi$ and $e^+e^-\to 3\pi$	*Martin Hoferichter*	16:00 - 16:20
Mix leptonic and hadronic contribution to a_mu^HLO	*Thomas Teubner*	16:20 - 16:30
Discussion: Towards NNLO MC generators for e+e- -> hadrons, leptons		16:30 - 17:00

MCGPJ and ReneSANCe MC event generators: status and perspectives

Andrej Arbuzov

BLTP, JINR, Dubna

The BabaYaga event generator: overview and future prospects

C.M. Carloni Calame

Monte Carlo generator Phokhara

H. CZYŻ, IP, US, Chorzów, Poland

KKMCee/BHLUMI/BHWIDE MC generators: status and prospects

Stanisław Jadach

KKMC: new tau decays, vector/scalar resonances of New Physics

Sw. Banerjee[a], D. Biswas[a], T. Przedzinski[b], Z. Was[*]

Bhabha: MCGPJ vs Babayaga@NLO

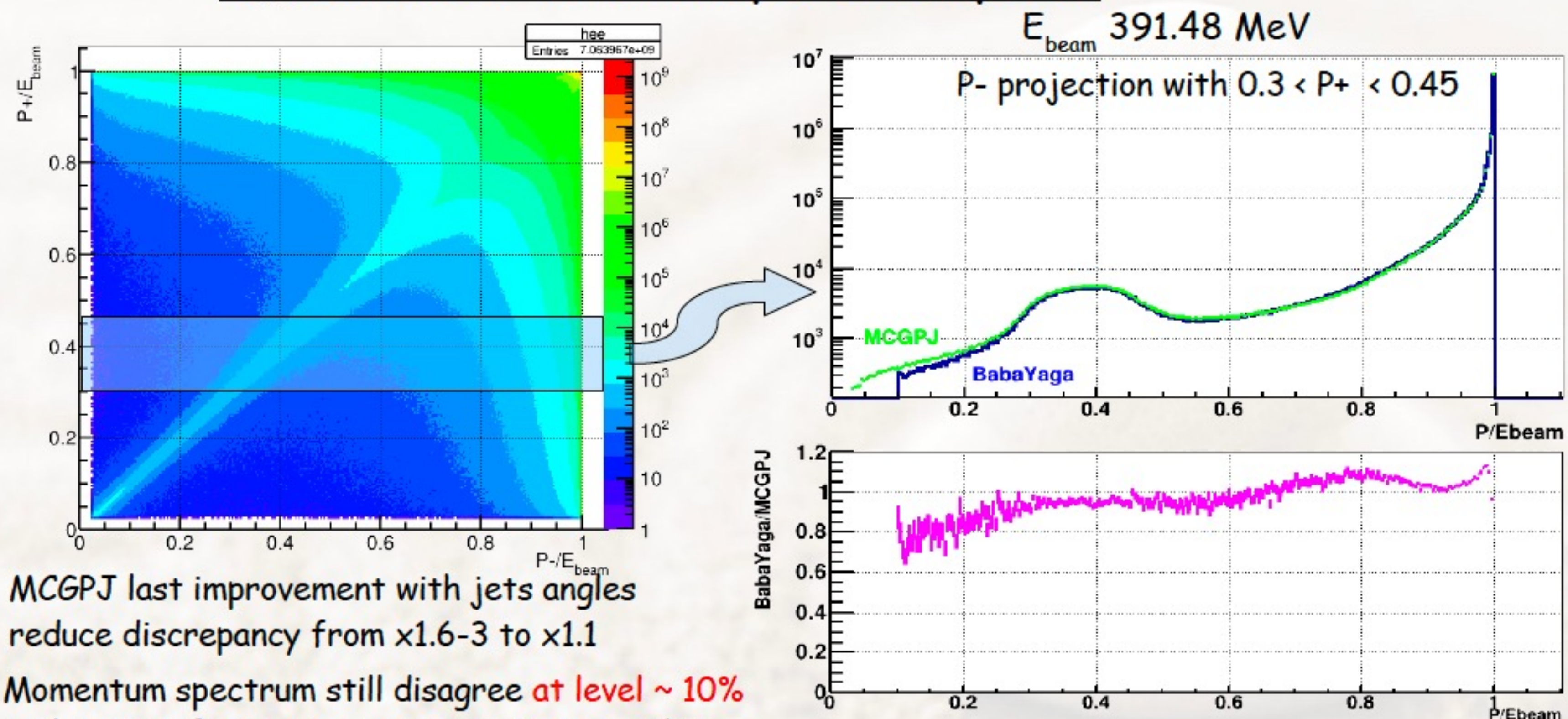
F. Ignatov

(CDM3 selection cuts)

RADIO MONTECARLOW

MCGPJ vs BabaYaga bhabha P+ vs P- spectrum

Differential over momentum spectrum comparison



MCGPJ last improvement with jets angles reduce discrepancy from x1.6-3 to x1.1

Momentum spectrum still disagree at level ~ 10%

Tails comes from $e^+e^- \to e^+e^- \gamma\gamma$, NNLO order

Very desirable to have more precise generators

Such discrepancy gives 0.3% systematic for $\pi^+\pi^-$ at ρ-peak using momentum analysis at CMD3

ISR: NLO $e^+e^- \to \pi^+\pi^-\gamma$

H. Czyz

Status - finished

PHYSICAL REVIEW D 100, 076004 (2019)

Francisco Campanario, Henryk Czyż , Janusz Gluza, Tomasz Jeliński,
German Rodrigo, Szymon Tracz, and Dmitry Zhuridov

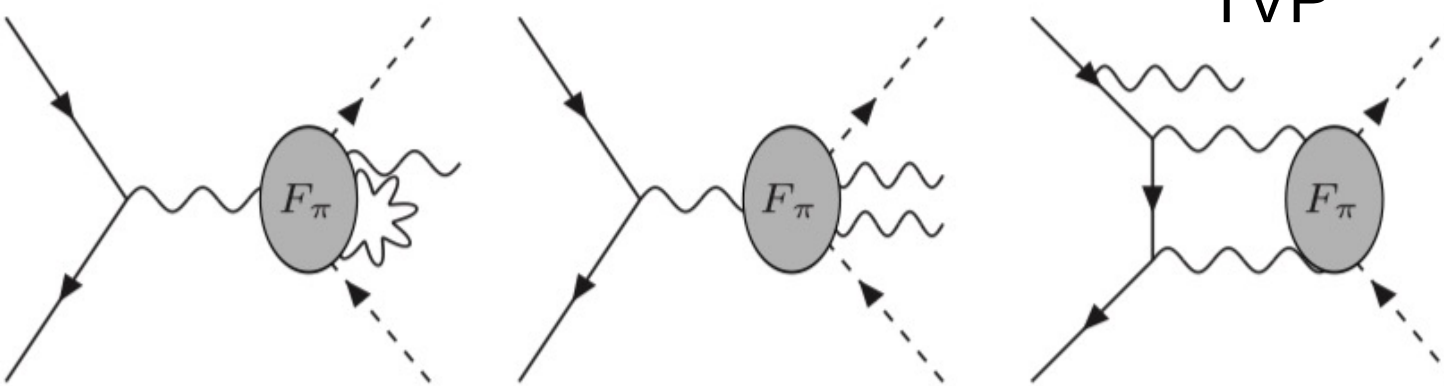
⇒ sQED + form factors:
FSR at NLO and pentaboxes ready and fully tested

⇒ Phokhara10.0
http://ific.uv.es/∼ rodrigo/phokhara/

ario et al.
PRD100 (2019) 7, 076004

FSRNLO

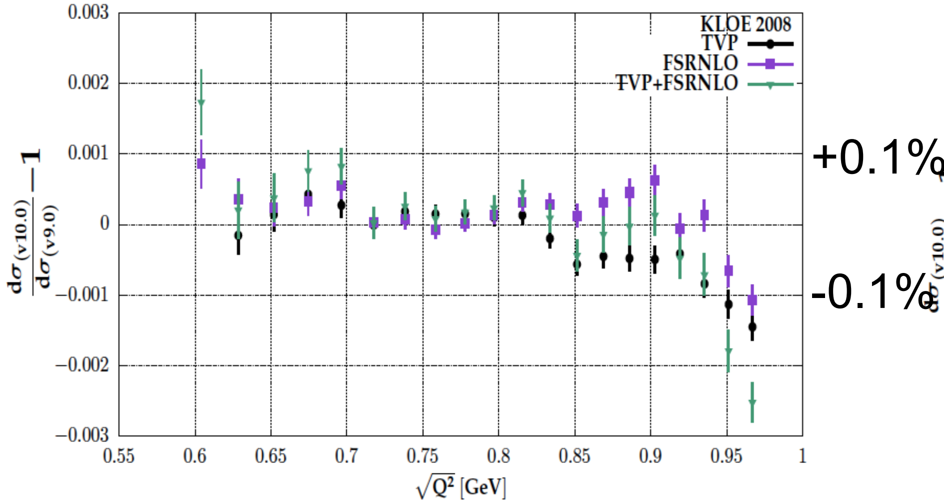
TVP



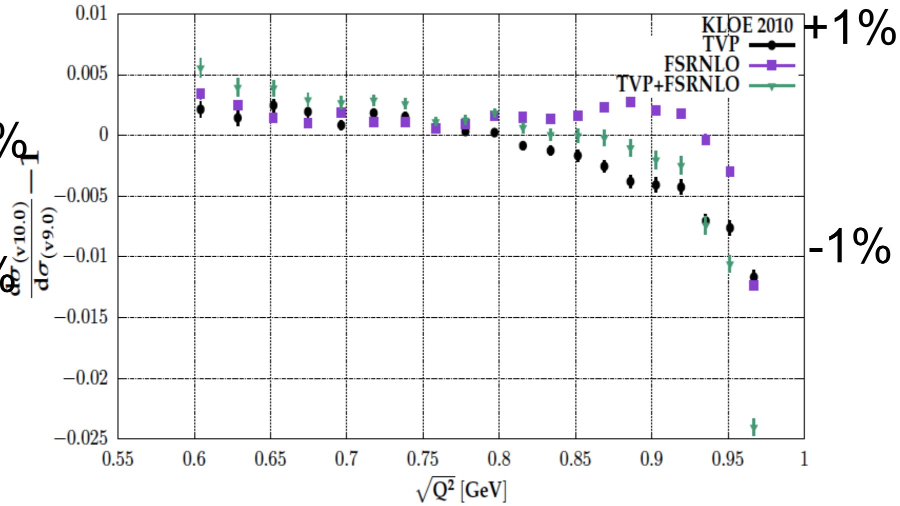
a) b) c)

Effect of NLO missing corrections in previous version of PHOKHARA (used by experiments)

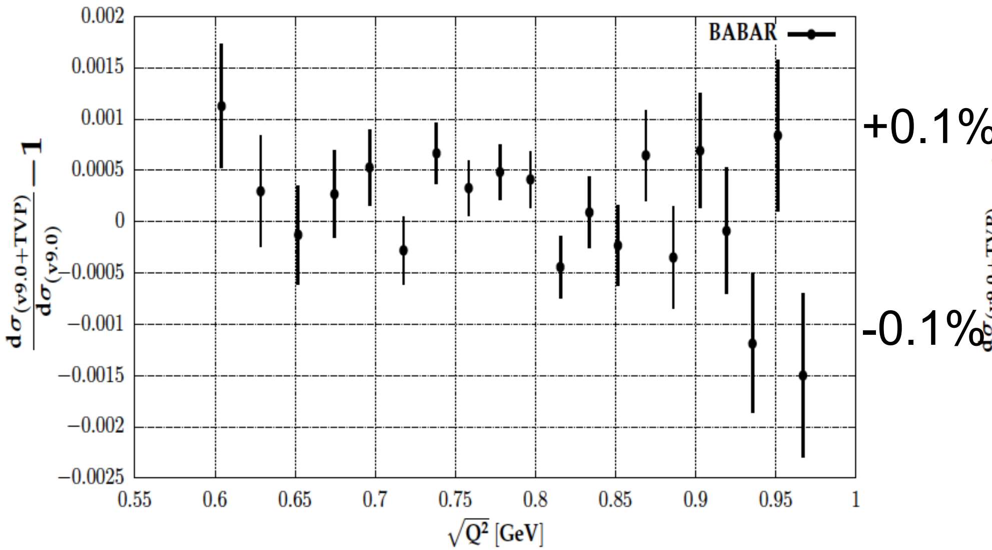
Complete NLO: KLOE-small



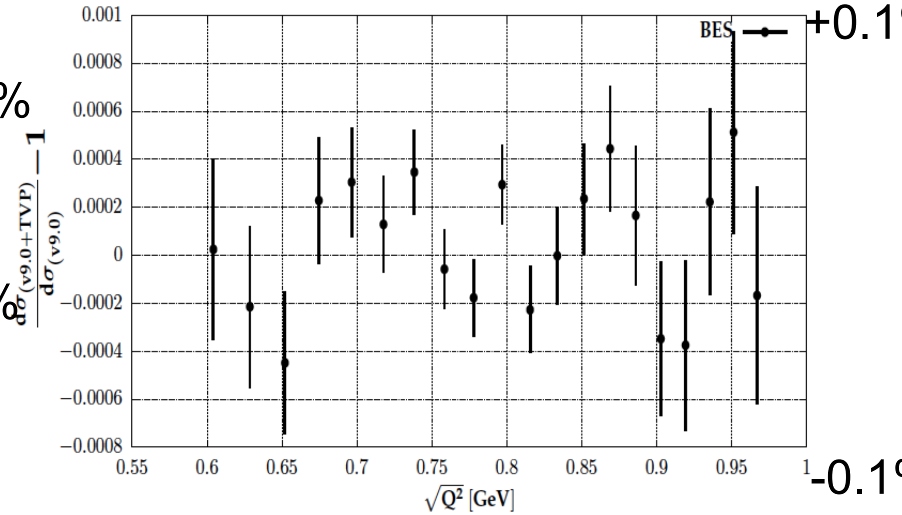
Complete NLO: KLOE-large



Complete NLO: BaBar



Complete NLO: BES



Conclusions

H. Czyz,
TI Workshop 2019

⇒ arXiv:1903.10197(tbp in PRD) and JHEP 1402 (2014) 114

show that missing NLO radiative corrections

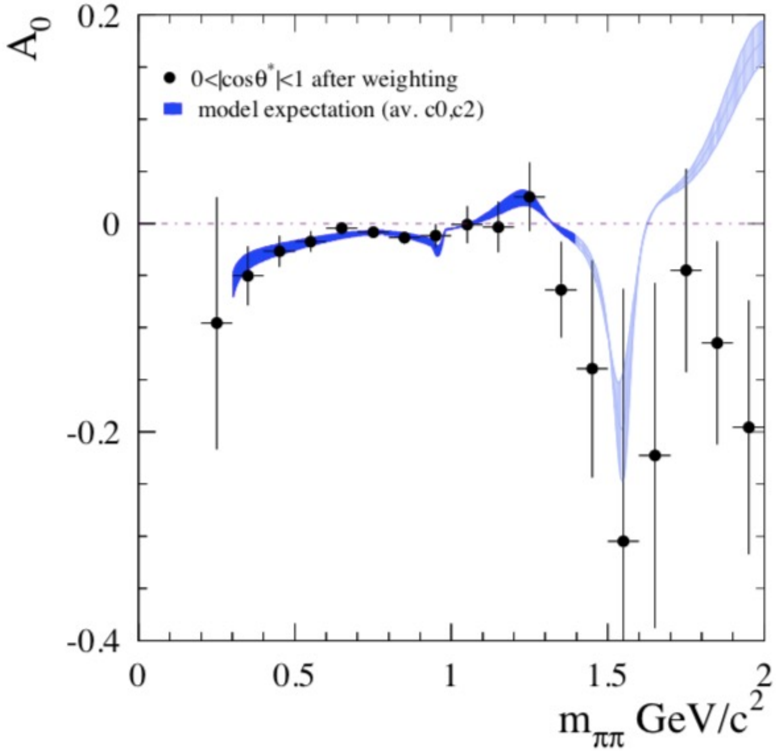
cannot be the source of the discrepancies between

the different extractions of the pion form factor

performed by BaBar, BES and KLOE

Test of FSR model for pions

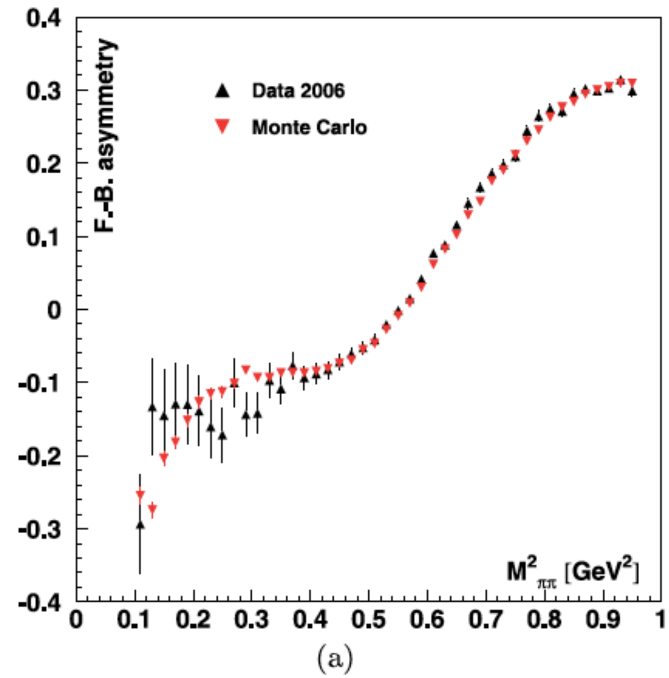
Charge asymmetry



BaBar vs AfkQed
PRD92 (2015) 7, 072015

Quark model for FSR by pions

F.B. asymmetry



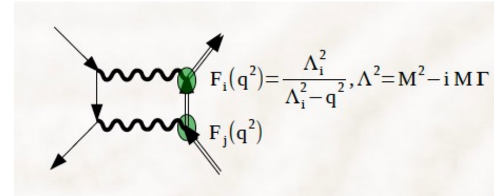
KLOE vs Phokhara
PLB634 (2006) 148
EPJC 66 (2010) 585

sQED model (pointlike pions) for FSR

Effect from FSR NLO can be as large as 5-10% at low $m_{\pi\pi}$ (EPJC33(2004) 333)

Form factor parametrization

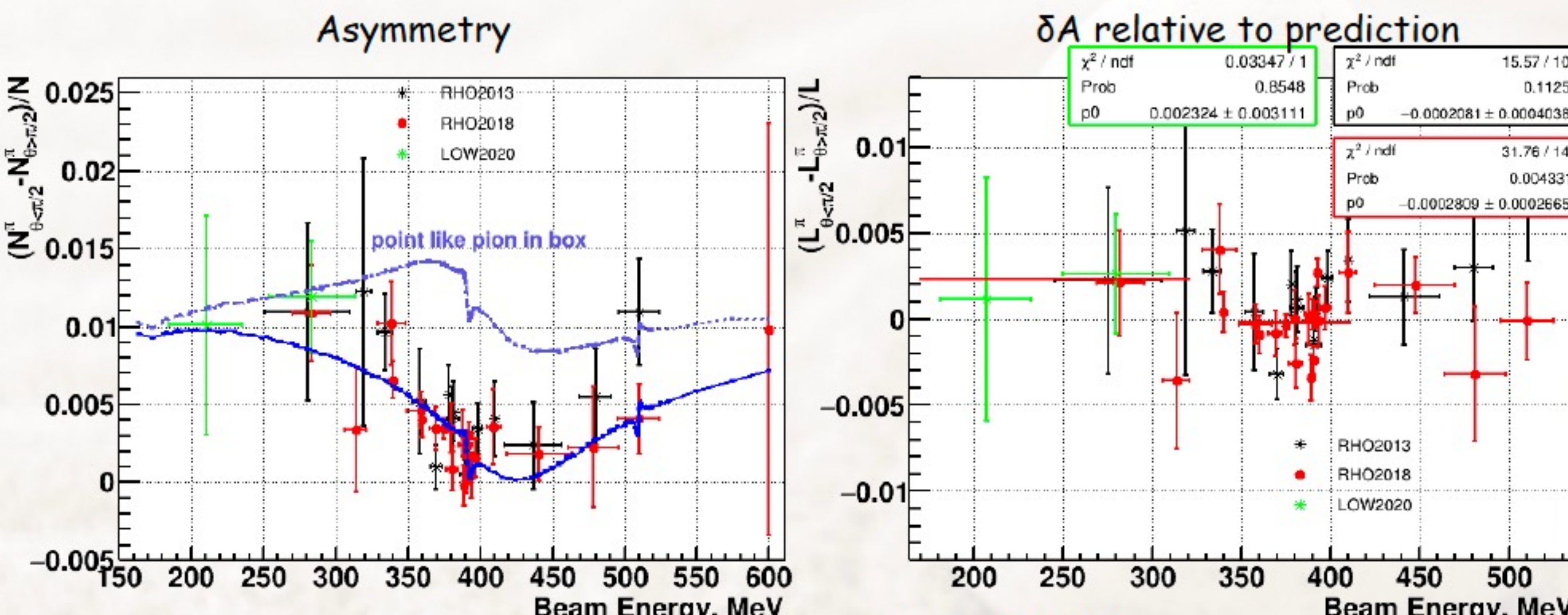
Inclusion of double FF



Asymmetry

F. Ignatov

After plugging δvFF in MCGPJ generator



at 2E=350-410 MeV

‹δA› = -1.035 ± 0.022 %

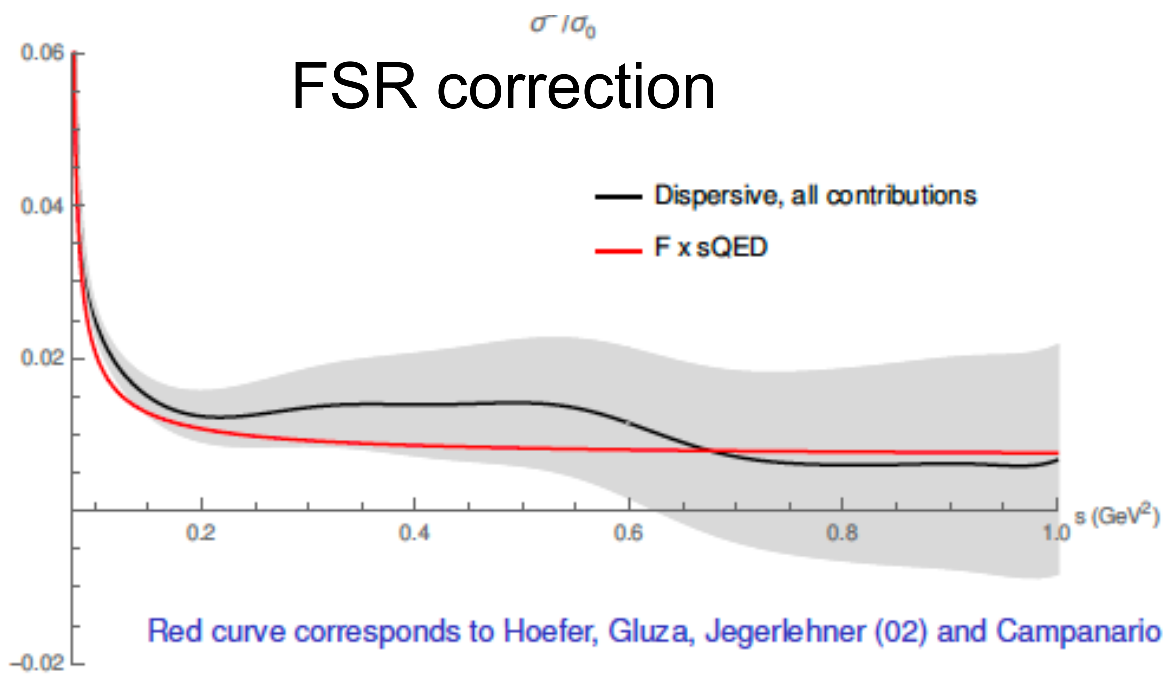
‹δA› = -0.026 ± 0.022 %

F. Ignatov, R. N. Lee
arXiv:2204.12235 [hep-ph]

Form factor parametrization

G. Colangelo

Dispersive treatment of FSR in $e^+e^- \to \pi^+\pi^-$



Red curve corresponds to Hoefer, Gluza, Jegerlehner (02) and Campanario et al. (19) (?)

See also G. Colangelo et al, arXiv:2207.03495

Going forward: Strong2020: a database for e^+e^- into hadrons

- European project (http://www.strong-2020.eu)
- WP21 — JRA3 PrecisionSM: "*Hadron Physics for Precision Tests of the Standard Model*"
- Goal: combine theory and experiment for precision tests SM & BSM
- **Task 2: Hadronic Effects in Precision Tests of the electromagnetic sector of the Standard Model: Muon g-2:**
  - 2.1 Hadronic Vacuum Polarization from spacelike and timelike processes
  - 2.2 Hadronic Light-by-Light Scattering Contribution to $(g-2)\mu$
- Deliverable for Task 2.1:
  - Annotated database for low-energy hadronic cross sections in e+e- collisions.

Conveners (Task 2): A. Kupsc (Uppsala), GV

Procedure

- Web page (https://precision-sm.github.io/)
- Input data (from HEPData)
- Check of «consistency» of input data
- Annotate the data according the treatment of RC,…
- Responsive Plots (cross section, covariance matrix,…)
- (Possible) Production of useful quantities (VP, α_{EM}, Adler Function…)
- Maintenance of the web page and polling to HEPData

Currently only $e^+e^- \rightarrow \pi^+\pi^-$ channel

PrecisionSM Contents Docs About RSS feed Search

PrecisionSM web site (work in progress)

- Measurements Database
- HEPData submissions
  - cured by PrecisionSM
- HEPData submissions checks
- Plots

PrecisionSM Contents Docs About RSS feed Search

Measurements Database

(download)

channel	experiment	year	ref	hepdata	details
$\pi^+\pi^-$	BCF (ADONE, Frascati)	1975	ref	hepdata	details
$\pi^+\pi^-$	MEA (ADONE, Frascati)	1977	ref	hepdata	details
$\pi^+\pi^-$	MEA (ADONE, Frascati)	1980	ref	hepdata	details
$\pi^+\pi^-$	CLEOc (CESR, Cornell)	2005	ref		details
$\pi^+\pi^-$	CLEOc (CESR, Cornell)	2013	ref		details
$\pi^+\pi^-$	CLEOc (CESR, Cornell)	2018	ref		details
$\pi^+\pi^-$	ACO (Orsay)	1972	ref	hepdata	details
$\pi^+\pi^-$	ACO (Orsay)	1976	ref	hepdata	details
$\pi^+\pi^-$	NA7 (Fixed target, CERN)	1984	ref	hepdata	details

PrecisionSM Contents Docs Abou

$\pi^+\pi^-$, BCF (ADONE, Frascati), 1975

- hepdata: ins100180
- method: Direct
- quotes: F_π
- energy [GeV]: 1.44 - 9
- rad_corr:
  - No Mention
- comment:
  - Errors not divided

PrecisionSM Contents Docs About RSS feed Search

HEPData submissions cured by PrecisionSM

PrecisionSM Group — 2022-04-30 00:00

$$e^+e^- \rightarrow \pi^+\pi^-(\gamma)$$

Novosibirsk Experiments

- Investigation of the ϱ-meson resonance with electron-positron colliding beams
  - Phys.Lett.B 25 (1967) 433-435, 1967.
  - *https://www.hepdata.net/record/ins1392895*
- Investigation of the rho-meson resonance with electron-positron colliding beams
  - Yad.Fiz. 9 (1969) 114-119, 1969.
  - *https://www.hepdata.net/record/18687*
- Electromagnetic Pion Form-Factor in the Timelike Region
  - *https://www.hepdata.net/record/6886*
- Measurement of the pion form-factor in the range 1.04-GeV to 1.38-GeV with the CMD-2 detector
  - *https://www.hepdata.net/record/41807*
- Pion Form-factor Measurement in the Reaction e+e−→π+π− for Energies Within the Range From 0.4-{GeV} to 0.46-{GeV}
  - *https://www.hepdata.net/record/18823*
- Measurement of the e+e−→π+π− process cross section with the SND detector at the VEPP-2000 collider in the energy region 0.525\<s\<0.883 GeV
  - *https://www.hepdata.net/record/114983*

HEPData

PrecisionSM Contents Docs About RSS feed Search

HEPData submissions

RSS feed

- 2021-11-22 12:00 — Submit HEPData BaBar 2012 $\sigma(e^+e^- \rightarrow \pi^+\pi^- (\gamma))$

Submit HEPData BaBar 2012 $\sigma(e^+e^- \to \pi^+\pi^-(\gamma))$

PrecisionSM Group — 2021-11-22 12:00

HEPData submit BaBar 2012 $\sigma(e^+e^- \to \pi^+\pi^-(\gamma))$

Paper

- Phys.Rev.D 86 (2012) 032013, 2012
- InspireHEP 1114155

HEPData documentation for submissions

- https://hepdata-submission.readthedocs.io/en/latest/

Requirements

- hepdata_lib python3 library
  - ROOT with Python3 libraries
  - ImageMagick
  - Make sure that you have `ROOT` in your `$PYTHONPATH` and that the `convert` command is available by adding its location to your `$PATH` if needed.

Notes

In the supplementary material, numbers are printed into strings. We do not convert these strings to numeric format when reading the supplementary material, since the hepdata_lib code works with strings as well.

In [

PrecisionSM Contents Docs About RSS feed Search

Plot BaBar 2012 $\sigma(e^+e^- \to \pi^+\pi^-(\gamma))$

PrecisionSM Group — 2020-06-10 19:52

Plot BaBar $\sigma(e^+e^- \to \pi^+\pi^-(\gamma))$

The latest BaBar measurements are published in two papers, a PRL and a later PRD containing more detailed information. Both papers report the cross-section information in the supplemental material, in ASCII files that are identical.

- B. Aubert et al. [BaBar Collaboration], Phys. Rev. Lett. 103 (2009) 231801, inspirehep,
  "Precise measurement of the e+ e- ---> pi+ pi- (gamma) cross section with the Initial State Radiation method at BABAR"
- J. P. Lees et al. [BaBar Collaboration], Phys. Rev. D 86 (2012) 032013, inspirehep,
  "Precise Measurement of the e+e− → π+π−(γ)e+e−→π+π−(γ) Cross Section with the Initial-State Radiation Method at BABAR"
  - supplemental material folder
    - BABAR_ISR2pi_EPAPS.txt

The data report the "**bare cross section including FSR**" in nb, and in detail:

- the cross-section and its total undertainty in variable-width bins of energy
- the per-mil relative systematic uncertainty (per energy bin, 100% correlated on all bins)
- the statistical correlation between any two bins of cross-section

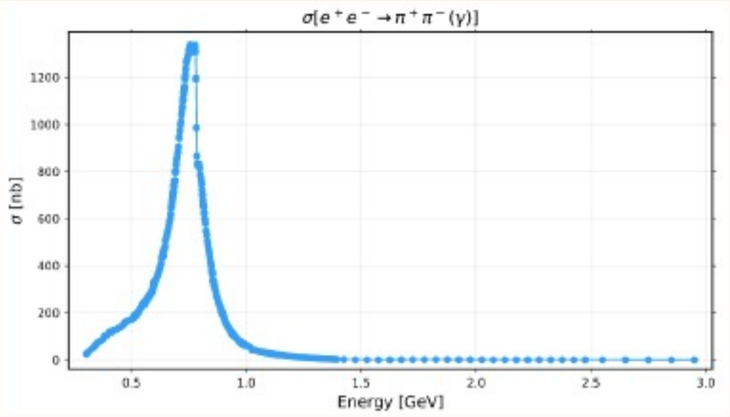
In the following the data are used to show a few plots using the Julia language.

Web site, read BaBar $e^+e^- \to \pi^+\pi^-(\gamma)$ and make plots

cross-section

In [56]:
```
##
## plot cross-section vs. energy (stat. unc. only)
##
curpl = @df sigma_df plot(
  :E,
  :sigma_val,
  yerror = :sigma_unc,
  title = L"$\sigma[e^+e^- \rightarrow \pi^+\pi^-(\gamma)]$",
  xlabel = "Energy [GeV]",
  ylabel = L"$\sigma$ [nb]",
  markerstrokecolor = :auto,
  legend = false
)
## mysavefig(curpl, "curpl.pdf")
## display(curpl)
```

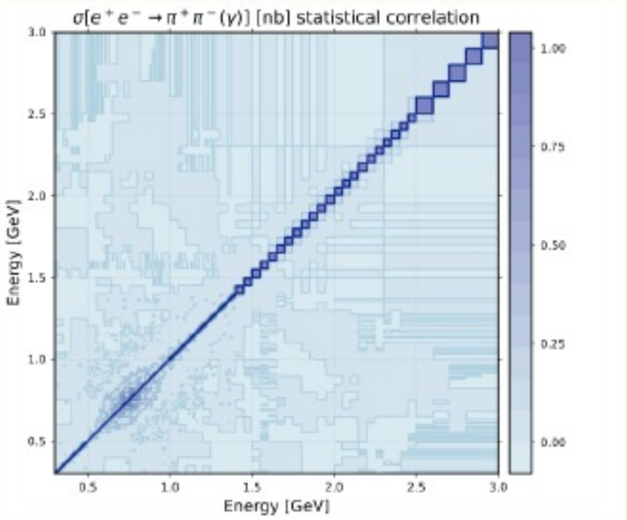
Out[56]:



correlation

In [65]:
```
##
## plot statistical correlation contour plot
##
curpl = @df sigma_df contourf(
  range(extrema(vcat(:E_l, :E_h))..., length=500),
  range(extrema(vcat(:E_l, :E_h))..., length=500),
  sigma_stat_corr,
  ## clims = sigma_stat_corr_clims,
  color = :blues,
  title=L"$\sigma[e^+e^- \rightarrow \pi^+\pi^-(\gamma)]$ [nb] statistical correlation",
  xlabel="Energy [GeV]",
  ylabel="Energy [GeV]",
  size=(600, 500)
)
```

Out[65]:



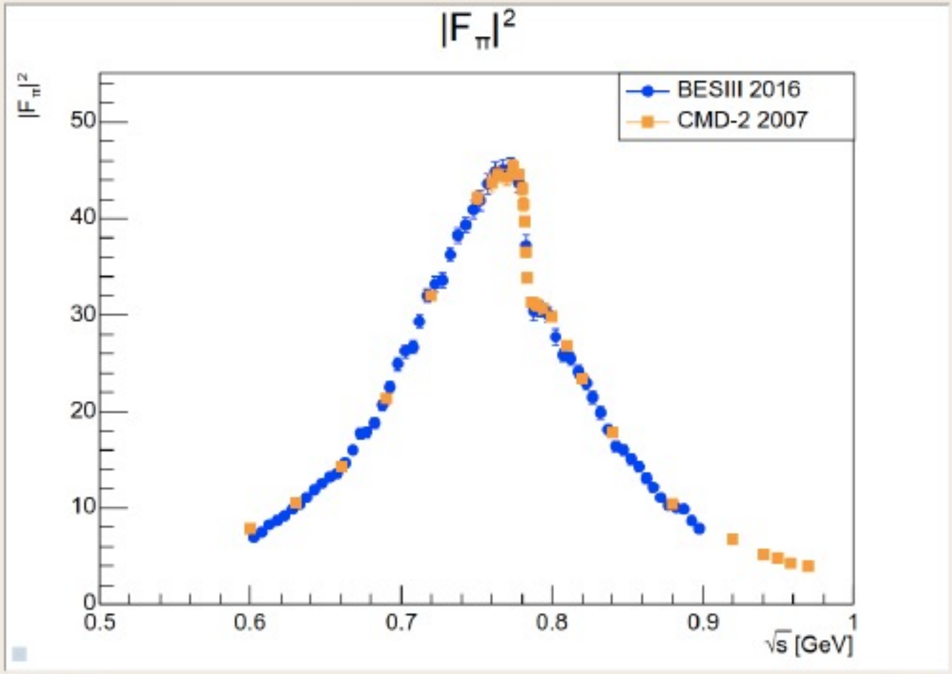
Web site, example of responsive plot

PrecisionSM Posts About RSS feed Search

PrecisionSM Group — 2020-09-06 14:36

Example responsive plot

Hovering the cursor above the points reveals the respective x and y values.



Previous post

Next post

Conclusions

- A lot of effort in the last 20 years to improve MC generators and RC to e^+e^- into leptons/hadrons at low energy :
  - Accuracy between 0.2 and 0.5%
- New data and improved evaluation of a_μ^{HLO} requires improvement on MC generators at ~0.1% → **NNLO**?
- **Radio MonteCarLow** activity still important!

➢ **Workshop** on **"Radiative corrections and Monte Carlo tools for low-energy hadronic cross sections in e+e- collision"** is planned on for the week **05-09 June 2023** at the University of Zurich (LOC: A. Signer, G. Stagnitto, Y. Ulrich)

- **Strong2020** project will contribute with a database for low-energy hadronic cross sections in e^+e^- collisions with relevant information (RC treatment, syst errors,...)

If you are interested to contribute you are welcome!

END

Fully exclusive measurement

- ✓Photon with $E_{CM} > 3$ GeV, which is assumed to be the ISR photon
- ✓All final hadrons are detected and identified

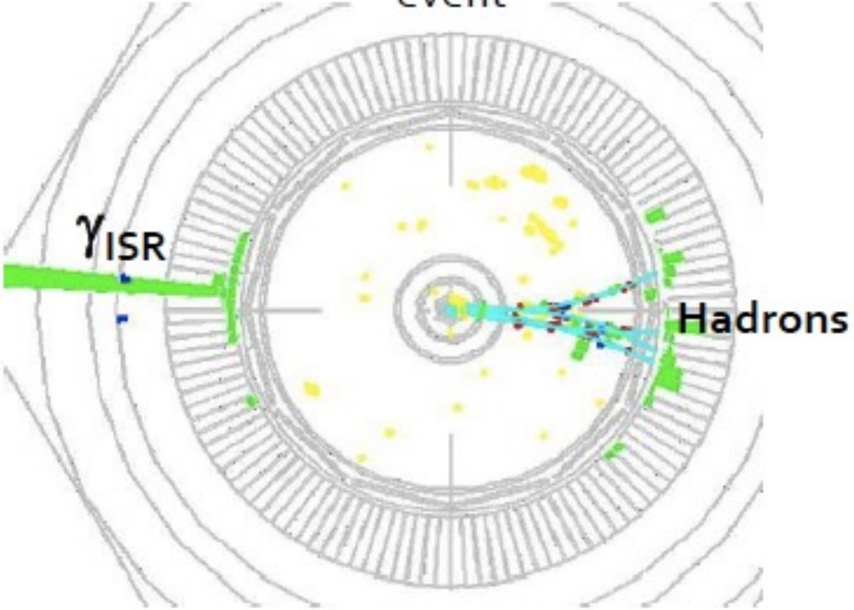
Large-angle ISR forces the hadronic system into the detector fiducial region

- ✓A weak dependence of the detection efficiency on dynamics of the hadronic system (angular and momentum distributions in the hadron rest frame) ⇒ smaller model uncertainty
- ✓A weak dependence of the detection efficiency on hadron invariant mass ⇒ measurement near and above threshold with the same selection criteria.

Kinematic fit with requirement of energy and momentum balance

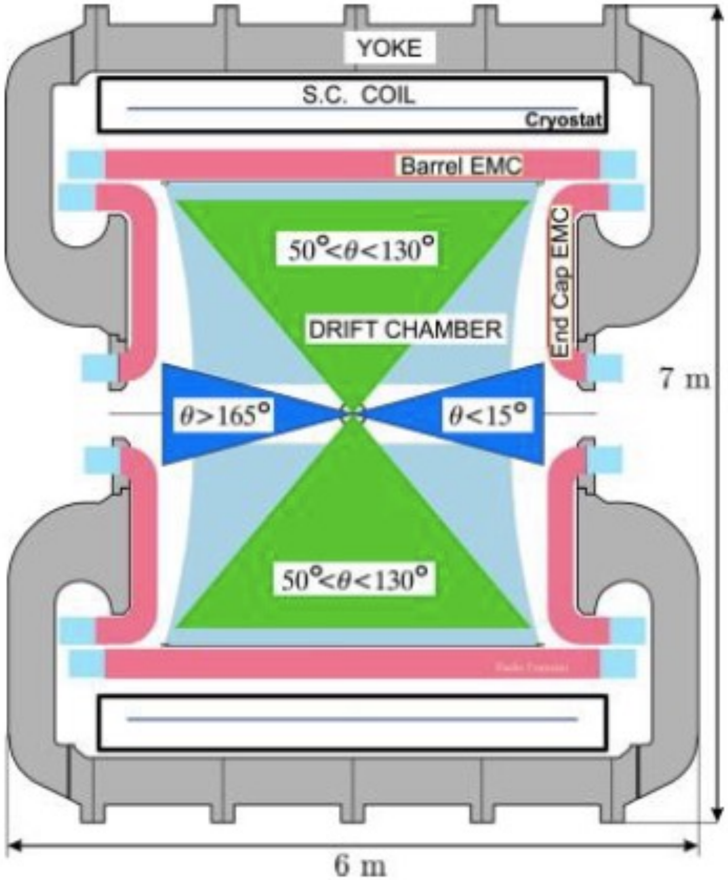
- ✓excellent mass resolution
- ✓background suppression

Generic BABAR ISR event



Can access a wide range of energy in a single experiment: from threshold to ~5 GeV

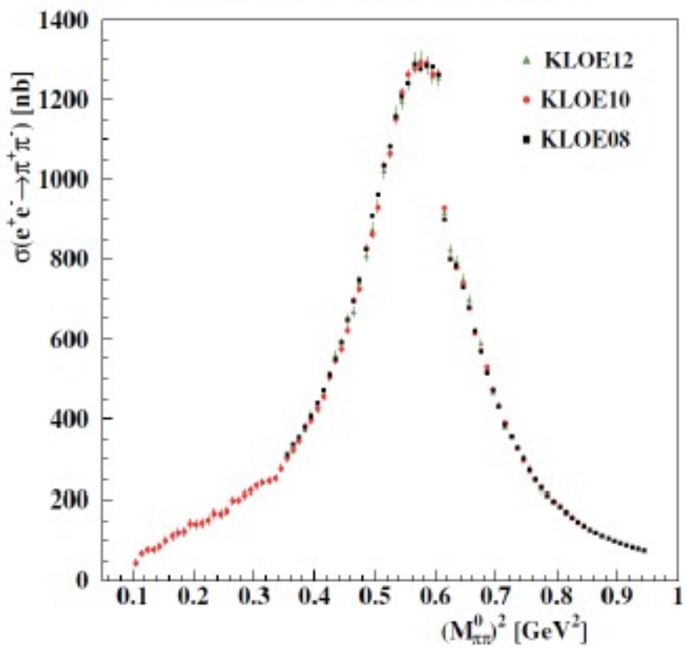
KLOE



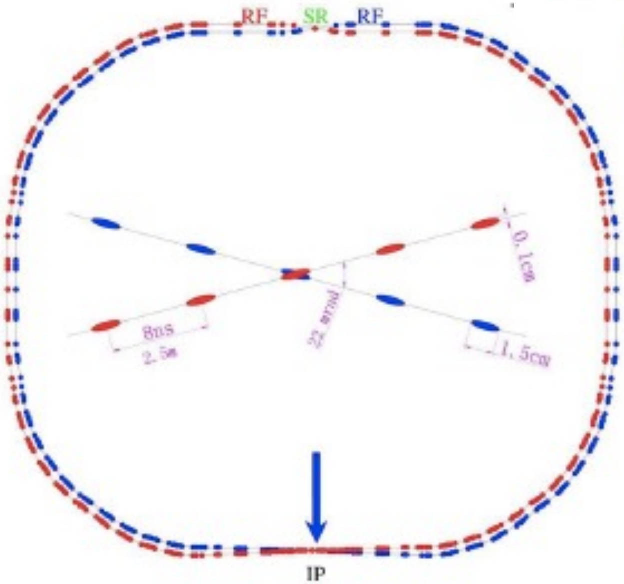
Installed at the DAFNE phi-factory

Mostly collected data at $\phi(1020)$ meson

ISR measurement of $\sigma(e^+e^- \to \pi^+\pi^-)$, both tagged and untagged



BESIII

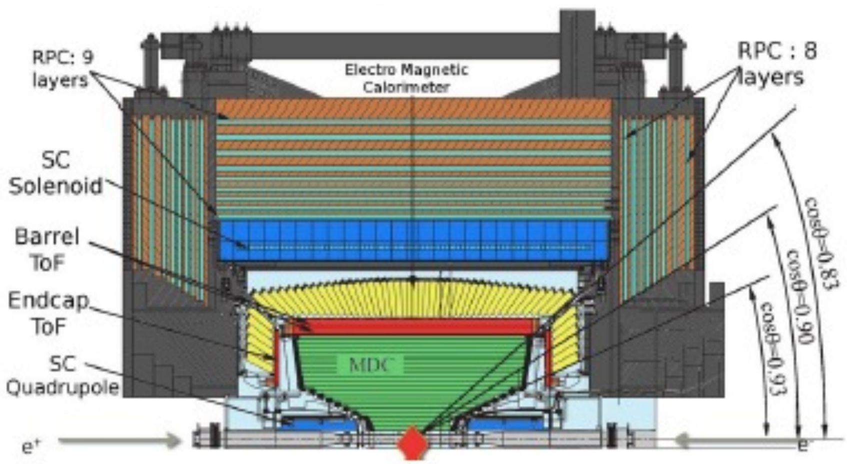


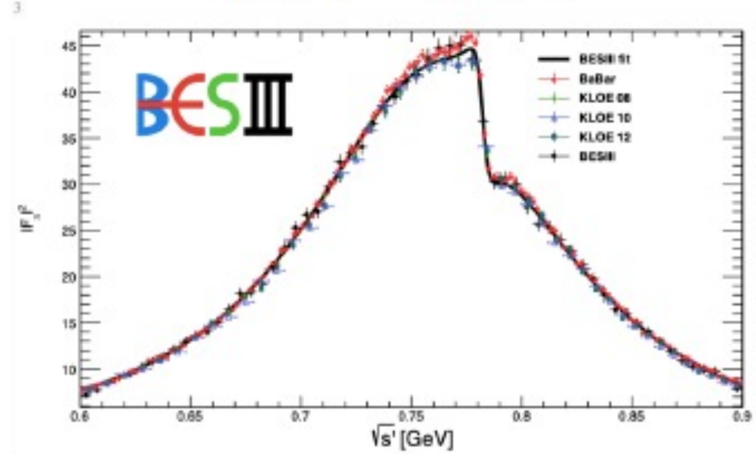
Beam energy: 1.0-2.3GeV
Luminosity: 1×10^{33} cm^{-2}s^{-1}
Optimum energy: 1.89 GeV
Energy spread: 5.16×10^{-4}
No. of bunches: 93
Bunch length: 1.5 cm
Total current: 0.91 A
SR mode: 0.25A @ 2.5 GeV

BEPC-II collider covers c.m.energy range from 2 to 5 GeV "$c\tau$-factory"

BES-III detector is taking data (and there were BES and BES-II before

Tagged ISR measurement $\sigma(e^+e^- \to \pi^+\pi^-)$





Statistics is limited compare to BaBar