Status of Radio MonteCarLow and Strong2020 activities

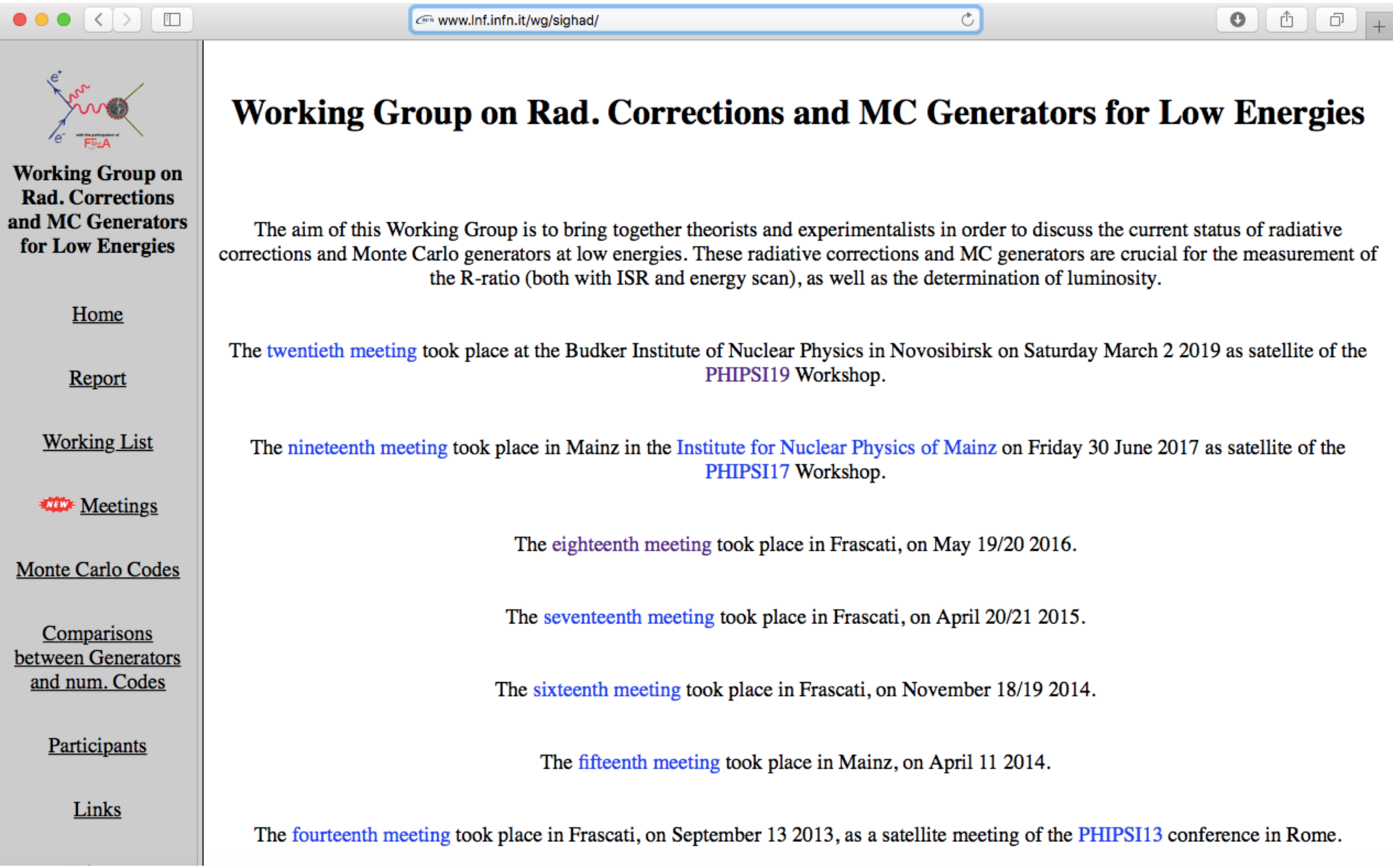
G. Venanzoni
INFN-Pisa

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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Monte Carlo Codes

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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

H. Czyż, IF, UŚ, Katowice, WG on RC and MC ... 4

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))

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

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

One has to measure :

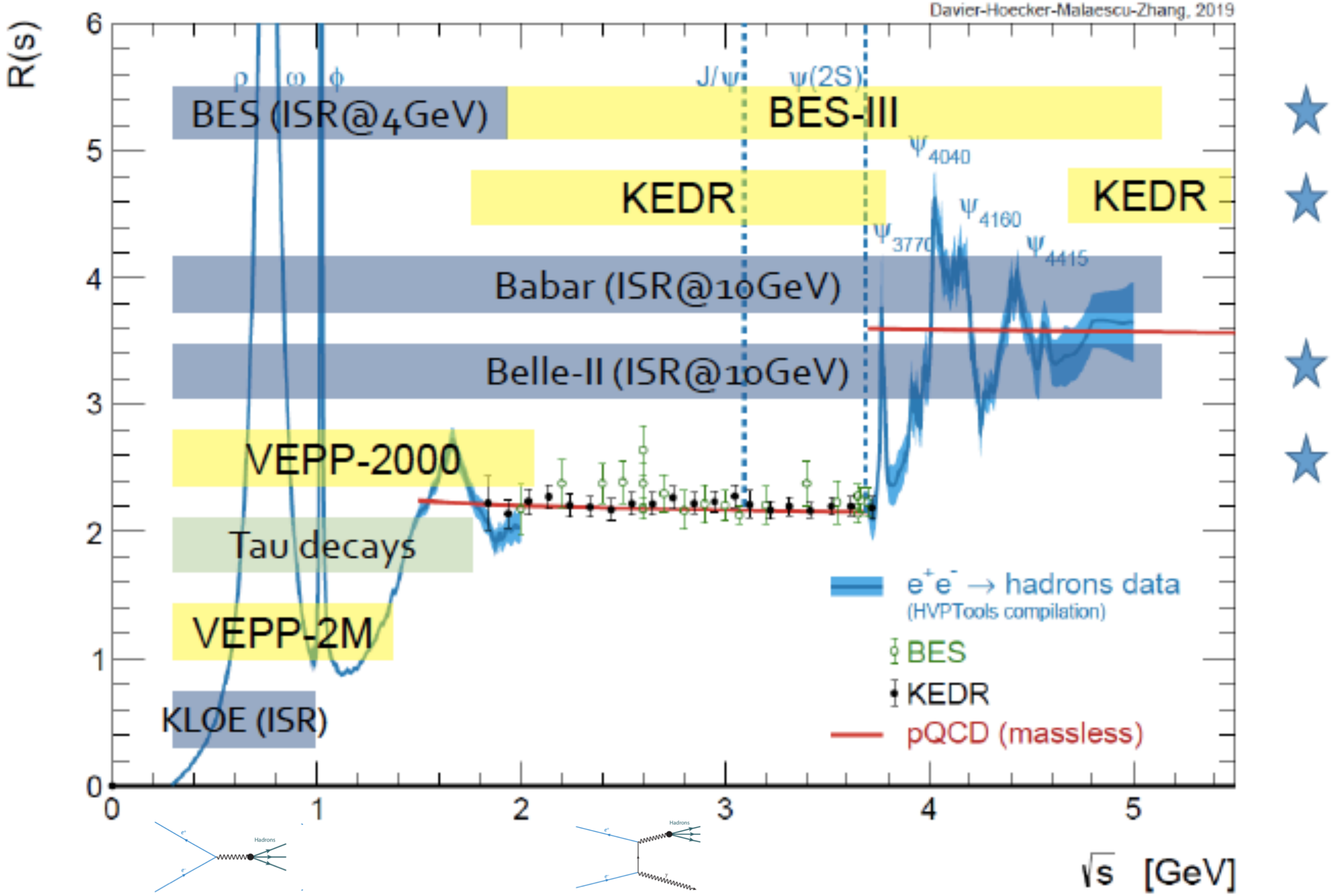
$$\sigma(e^+e^- \to hadrons)$$

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

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

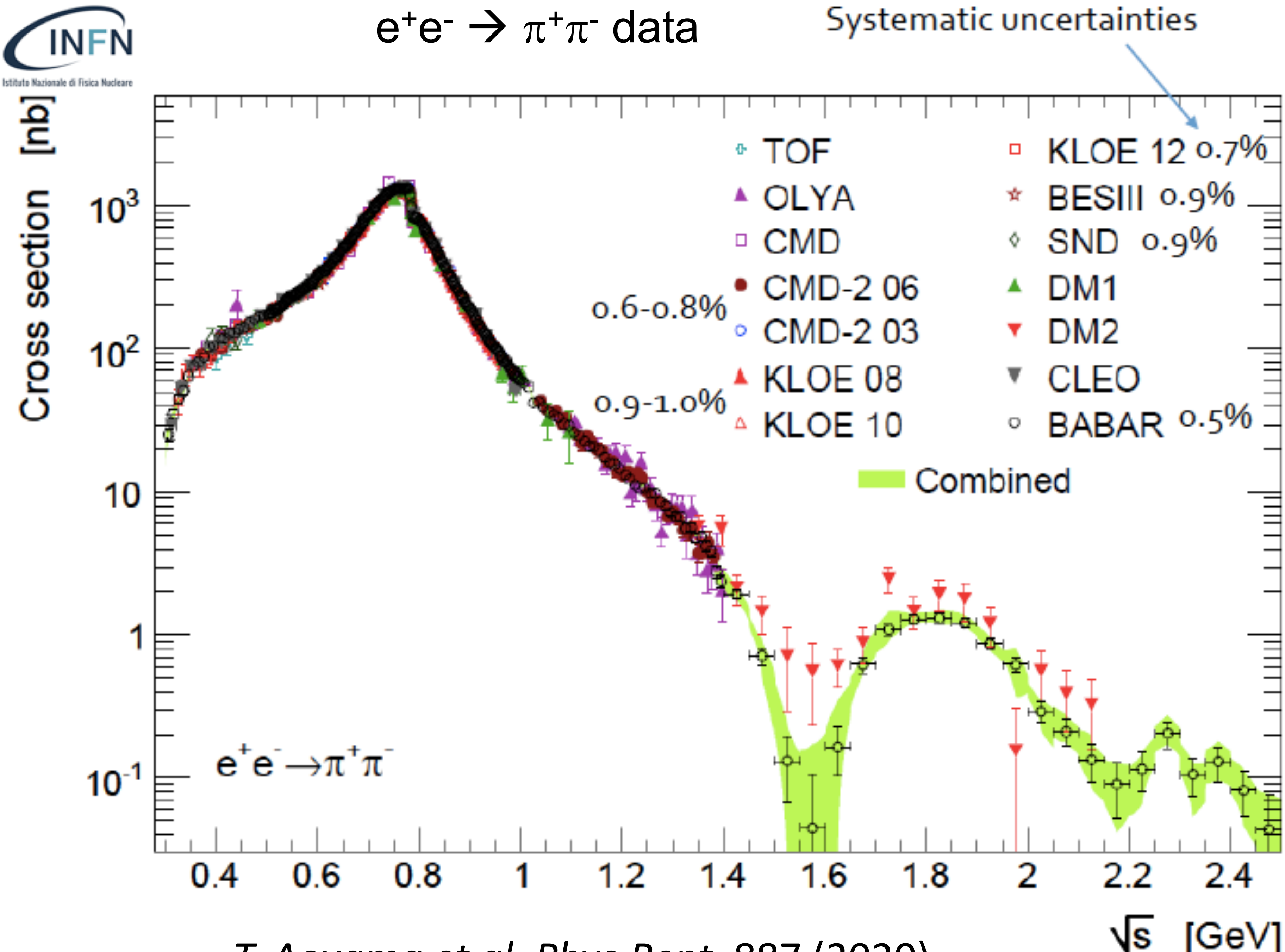
$$\delta a_\mu^{HLO}/a_\mu^{HLO}=0.6\%$$

e^+e^- into hadrons data



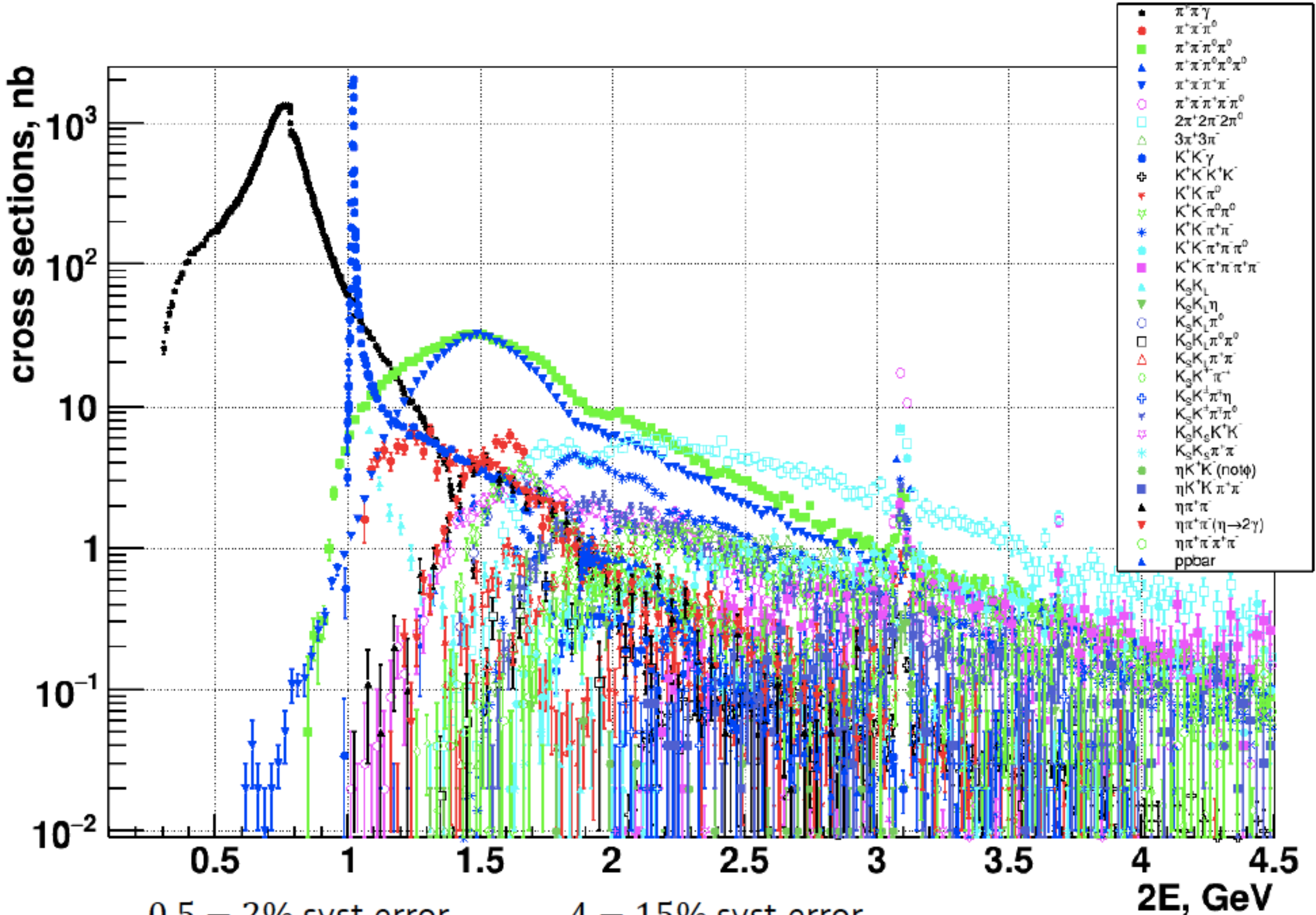
Energy scan | ISR | Tau decays

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



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

BaBar ISR data



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

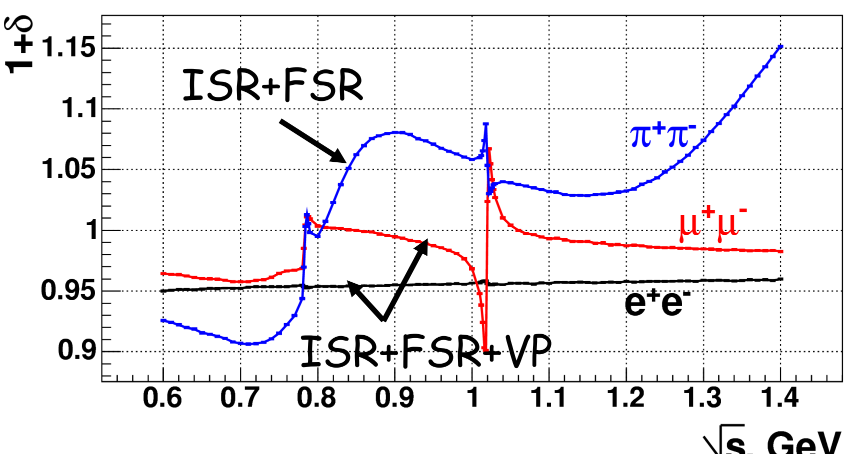
$$a_\mu^{\mathrm{had,LO}} = \frac{\alpha^2}{3\pi^2}\int_{4m_\pi^2}^{\infty}\frac{ds}{s}\,K(s)\,R(s)$$

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

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

- Ratio N(2π)/N(ee) is measured directly ⇒ 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)

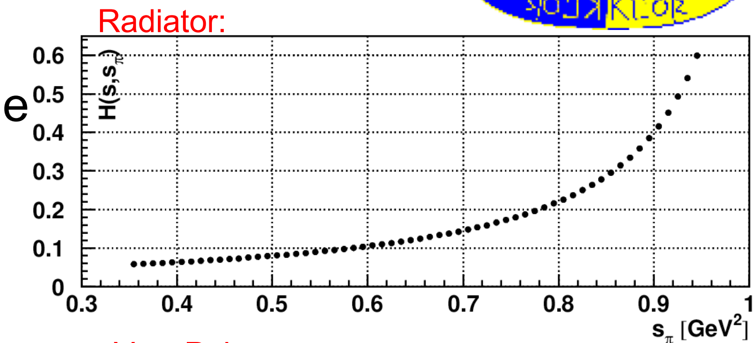
Radiator-Function $H(s,s_p)$ (ISR):

← It cancels in the ratio to $\mu\mu\gamma$

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

Precision: *0.5%*

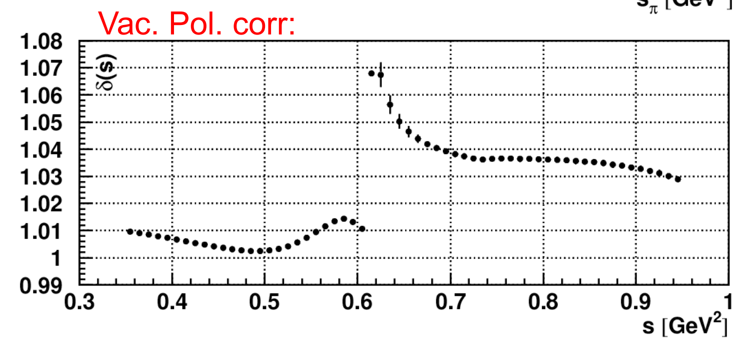
$$s \cdot \frac{d\sigma_{\pi\pi\gamma}}{ds_\pi} = \sigma_{\pi\pi}(s_\pi) \times H(s,s_\pi)$$



Radiative Corrections:

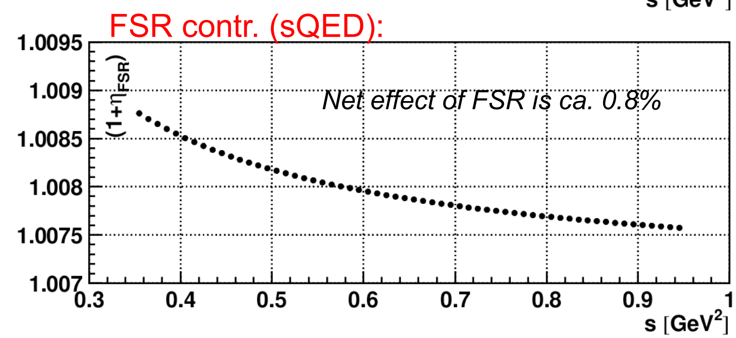
i) Bare Cross Section

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



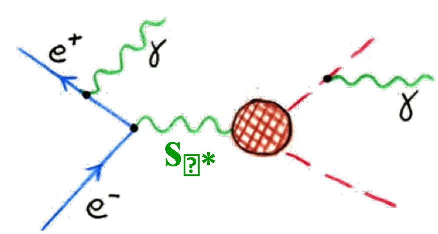
ii) FSR

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 $s_\pi \rightarrow s_{\gamma*}$

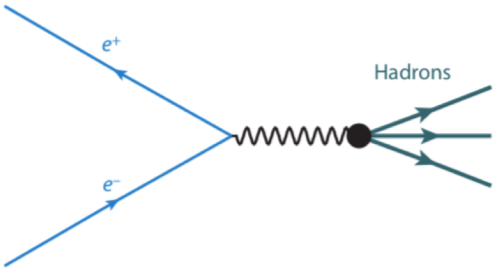
(H.Czyż, A.Grzelińska, J.H.Kühn, G.Rodrigo, EPJC33,2004)



$s_{\gamma*} > s_p$

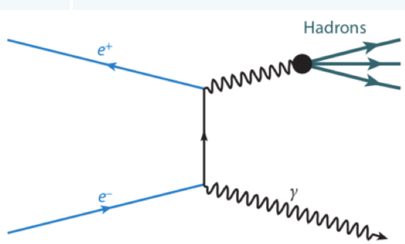
MC generators for exclusive channels
(exact NLO + Higher Order terms in some approx)

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	$e^+e^- \to f^+f^-\gamma$	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)

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

Studies on accuracy of the contributions from pair production in Babayaga generator - a status report

Michal Gunia

Working Group 'Radio Monte CarLow', Frascati

28 March 2011

RADIO MONTECARLOW

Table of contents

Cuts dependence study for different experiments

1.Φ factories KLOE/DAΦNE (Frascati)

(a) $\sqrt{s} = 1.02$ GeV
(b) $E_{min} = 0.4$ GeV
(c) For $\theta\pm$ two selections have to be checked
i. tighter selection $55^{\circ} < \theta\pm < 125\ ^{\circ}$
ii. wider selection $20^{\circ} < \theta\pm < 160\ ^{\circ}$
(d) ζ_{max}=4,5,6,7,8,...,14°, with reference value ζ_{max}=9°

2. B-factories BABAR/PEP-II (SLAC) & BELLE/KEKB (KEK)

(a) $\sqrt{s} = 10.56$ GeV
(b) $|\vec{p}_+|/E_{beam} > 0.75$ and $|\vec{p}_-|/E_{beam} > 0.50$
or $|\vec{p}_-|/E_{beam} > 0.75$ and $|\vec{p}_+|/E_{beam} > 0.50$
(c) For $|cos(\theta\pm)|$ the following selections have to be checked
i. $|cos(\theta\pm)| < 0.65$ and $|cos(\theta+)| < 0.60$ or $|cos(\theta-)| < 0.60$
ii. $|cos(\theta\pm)| < 0.70$ and $|cos(\theta+)| < 0.65$ or $|cos(\theta-)| < 0.65$
iii. $|cos(\theta\pm)| < 0.60$ and $|cos(\theta+)| < 0.55$ or $|cos(\theta-)| < 0.55$
(d) ζ^{3d}_{max}= 20,22,24,...,40°, with reference value ζ^{3d}_{max}=30 °

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Issues to be discussed here

Comparison of results with vacuum polarization obtained using :VPHLMNT (T.Teubner et all.) and hadr5n09 (F. Jegerlehner) (all results from BabaYaga) - all results in nb

KLOE: 55° $< \theta\pm <$ 125 °, ζ_{max}=4°
σ_{BY} =**436.85(5)**

vacpol	σ_h	σ_{v+s}	sum:
VPHLMNT(2009)	1.4346(5)	-1.126(2)	0.309(2)
hadr5n09	1.6264(6)	-1.405(2)	0.221(2)
relative difference: $\left\lvert\frac{\sigma^{NNLO}_{VPHLMNT}-\sigma^{NNLO}_{hadr5n09}}{\sigma_{BY}}\right\rvert$			0.201(6)‰

BES: $\sqrt{s}$ = 3.650 GeV, $|\cos\theta| < 0.8$
σ_{BY} = **116.41(2) nb**

vacpol	σ_h	σ_{v+s}	sum:
VPHLMNT2.0(2010)	1.6613(3)	-1.7860(2)	-0.1247(4)
hadr5n09	1.6471(7)	-1.7686(2)	-0.1215(7)
relative difference: $\left\lvert\frac{\sigma^{NNLO}_{VPHLMNT}-\sigma^{NNLO}_{hadr5n09}}{\sigma_{BY}}\right\rvert$			0.0275‰

MCGPJ

Systematic treatment of second order NLO QED radiative corrections to exclusive observables

Andrej Arbuzov

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

Talk at the Radio MontecarLow workshop, Frascati, 11th April 2008

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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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

→

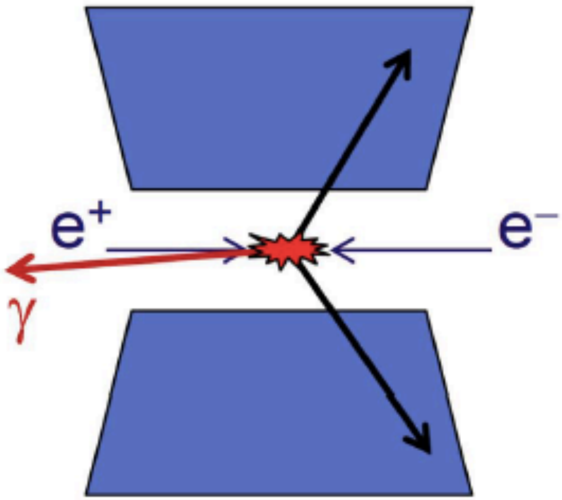
PHOKHARA 10.0: $\pi^+\pi^-$,$\mu^+\mu^-$,
4π, $\bar{N}N$, 3π, KK,$\Lambda\bar{\Lambda}$, $P\gamma$
$J/\psi, \psi(2S), \chi_{c1}, \chi_{c2}$

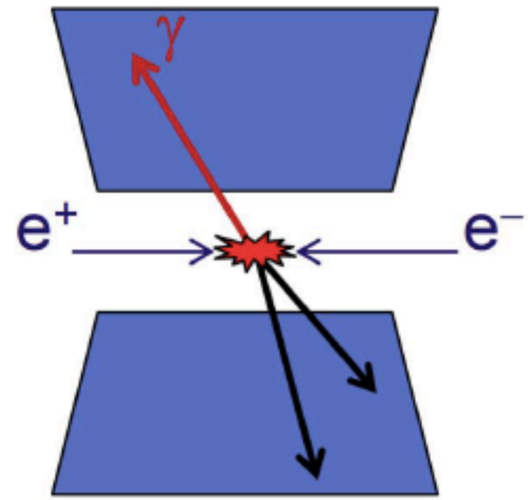
- **ISR at NLO:** virtual corrections to one photon events and two photon emission at tree level

- 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





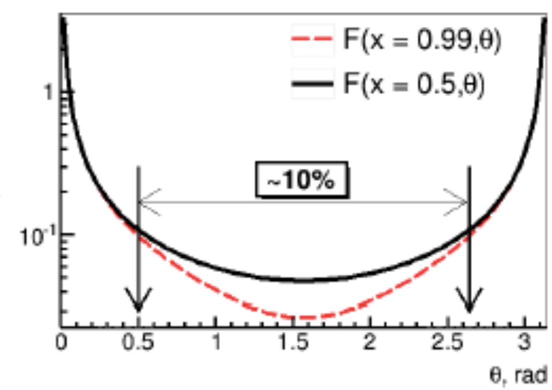
Small angle (untagged) ISR

- 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}



Fully exclusive measurement

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

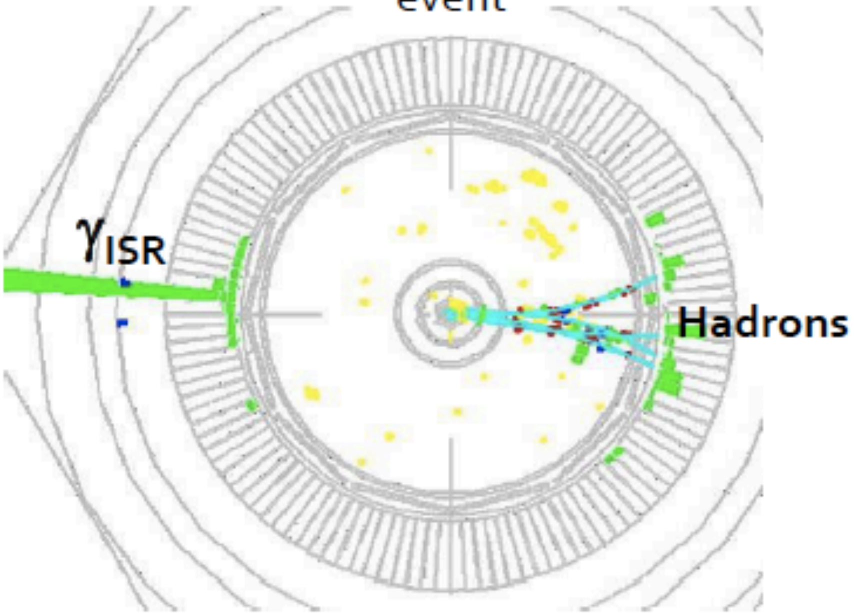
Large-angle ISR forces the hadronic system into the detector fiducial region

- ✓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

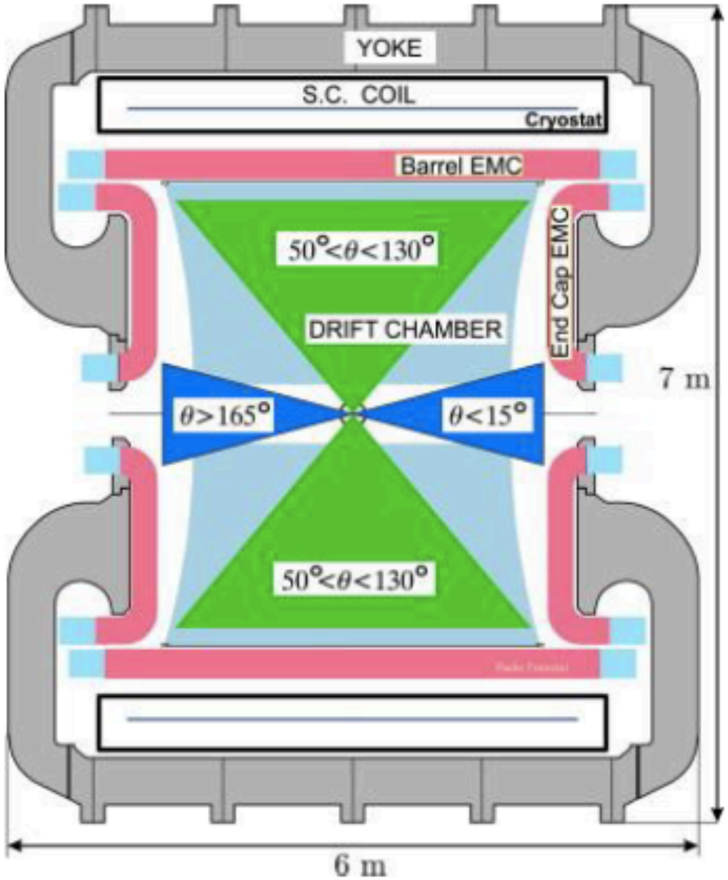
- ✓excellent mass resolution
- ✓background suppression

Generic BABAR ISR event



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

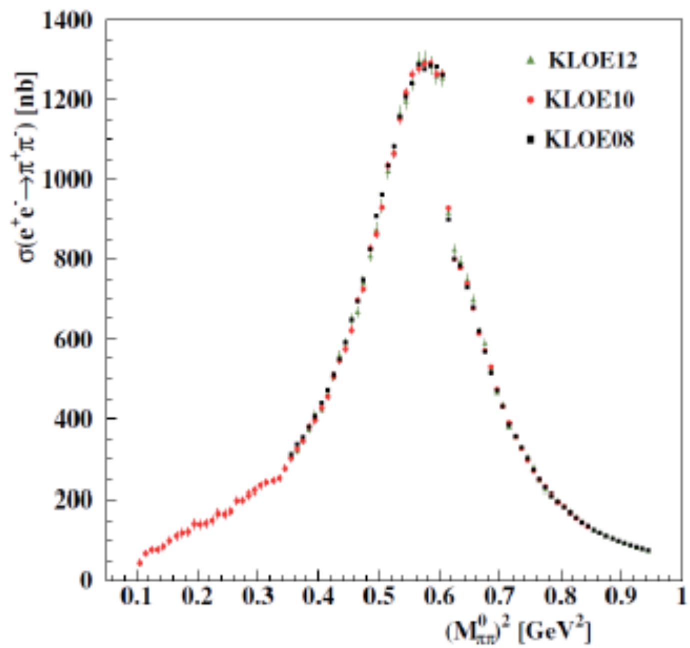
KLOE



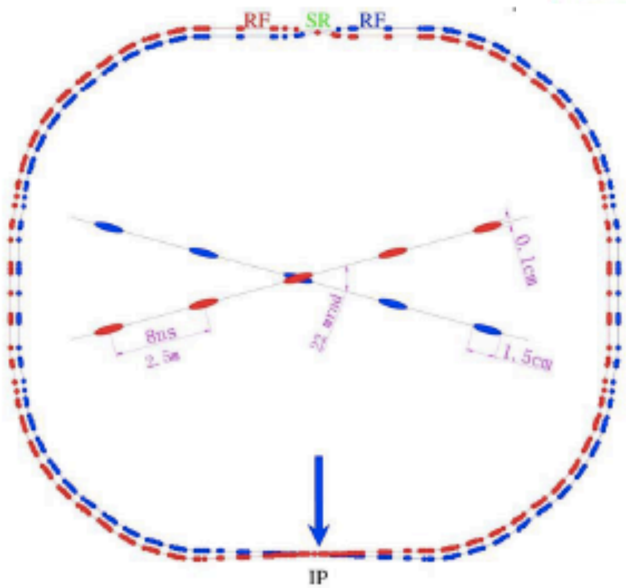
Installed at the DAFNE phi-factory

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

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



Data Input to HVP

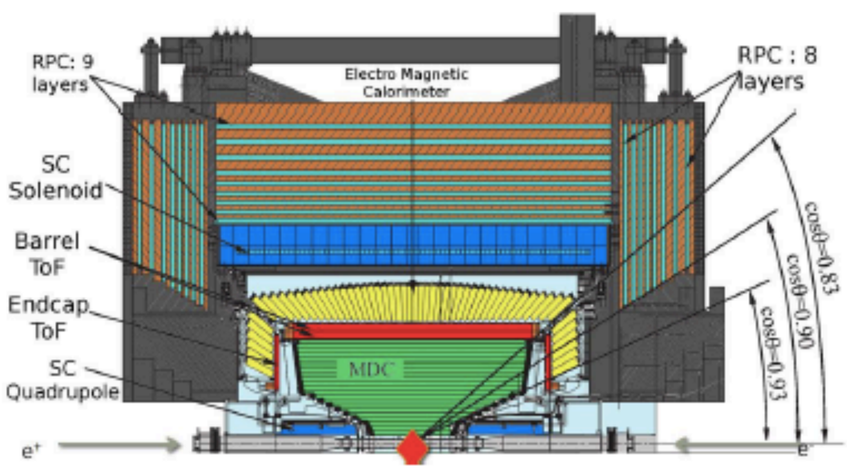


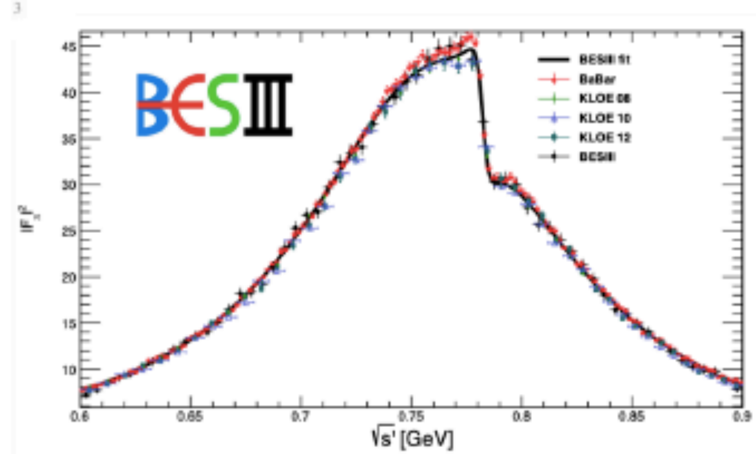
Beam energy: 1.0-2.3GeV
Luminosity: 1×10^{33} cm^{-2}s^{-1}
Optimum energy: 1.89 GeV
Energy spread: 5.16×10^{-4}
No. of bunches: 93
Bunch length: 1.5 cm
Total current: 0.91 A
SR mode: 0.25A @ 2.5 GeV

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

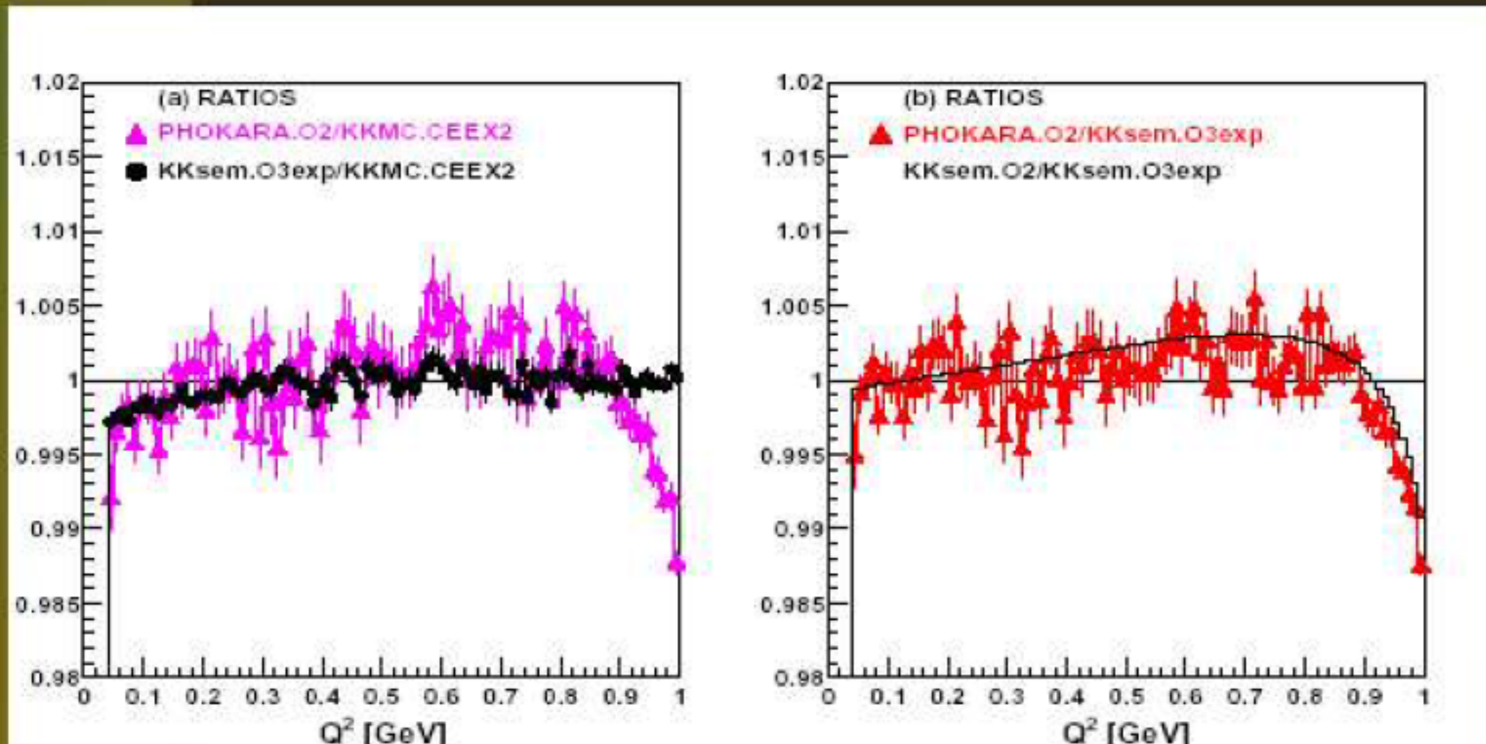
Different ISR approaches

	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 μμγ

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

H. Czyż, IF, UŚ, Katowice MC generators for ISR Frascati 2006 9

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

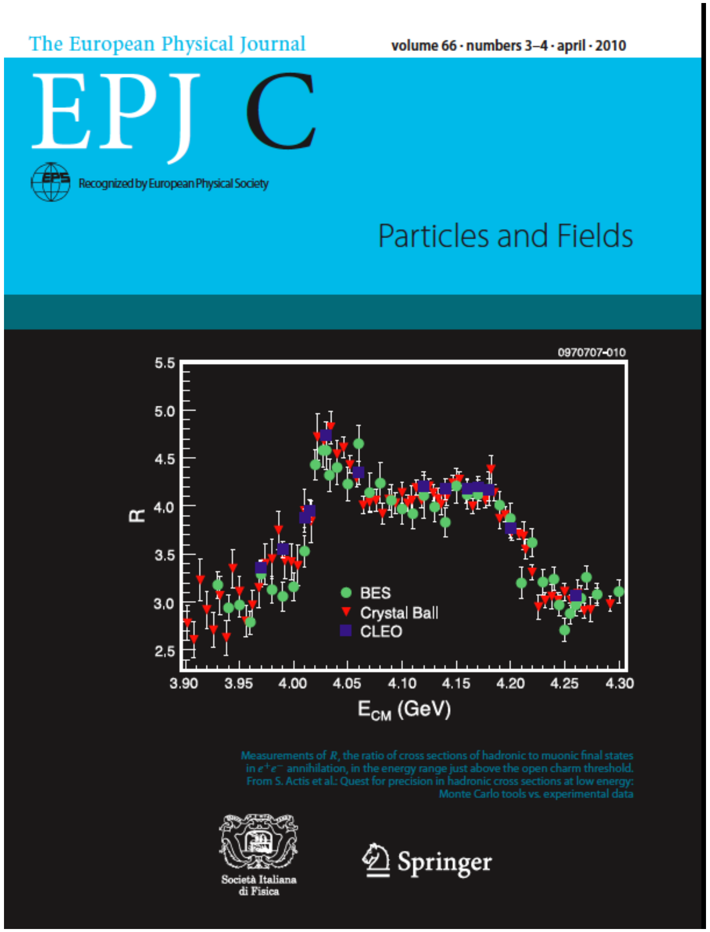
Review

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?

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)

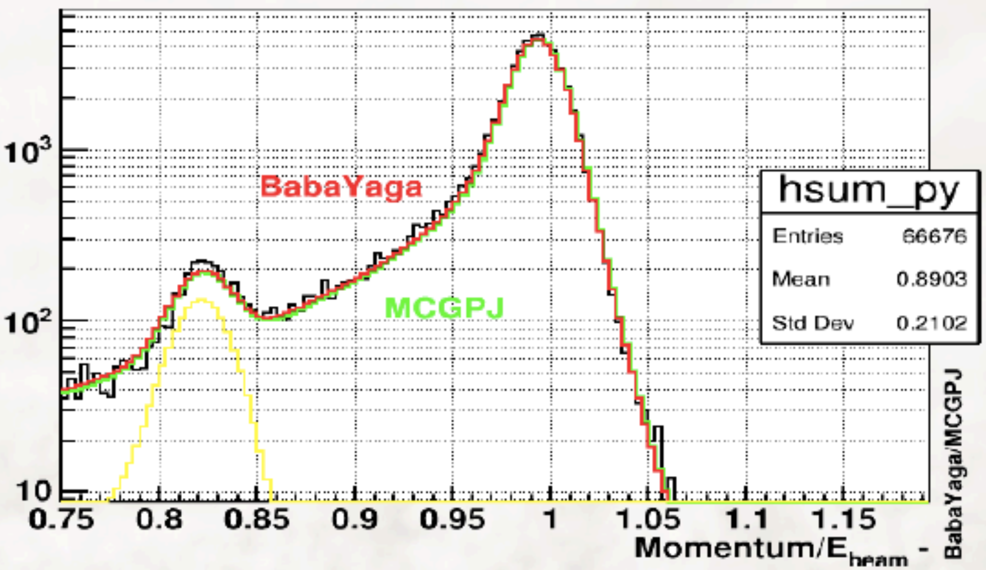
- Radio MC activity is still very important!!

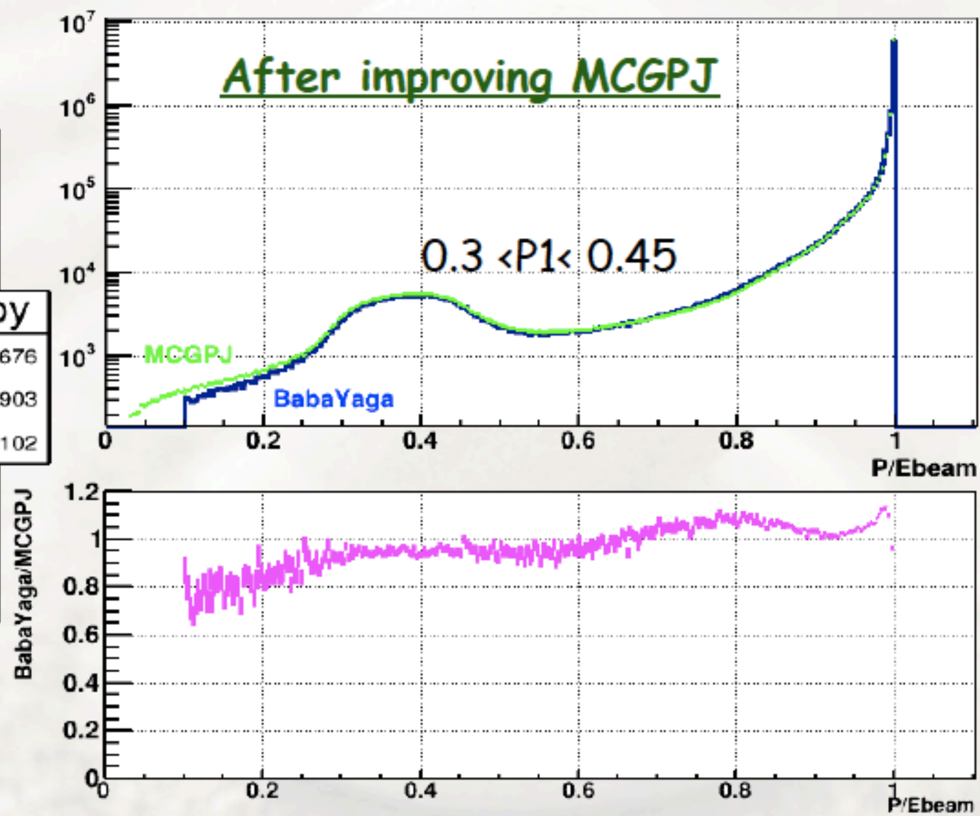
Bhabha: MCGPJ vs Babayaga@NLO (CDM3 selection cuts)

F. Ignatov

After adding angle distribution for jets, etc ...

Momentum spectrum still disagree at level ~ 10%
Need more experimental data for cross-check





Momentum spectrum disagree at level ~ 10%
Need more experimental data for cross-check
We need more theoretical input for MC

Result in systematic of π+π- measurement → 0.0 - 0.4%

ISR: Complete NLO for pions - tests

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H. Czyz,
TI Workshop 2019

⇒ two independent codes for the new hard part

⇒ the virtual corrections implementation:

the tensor reduction and the amplitude (trace) in quadruple(TPV) double(FSR) precision

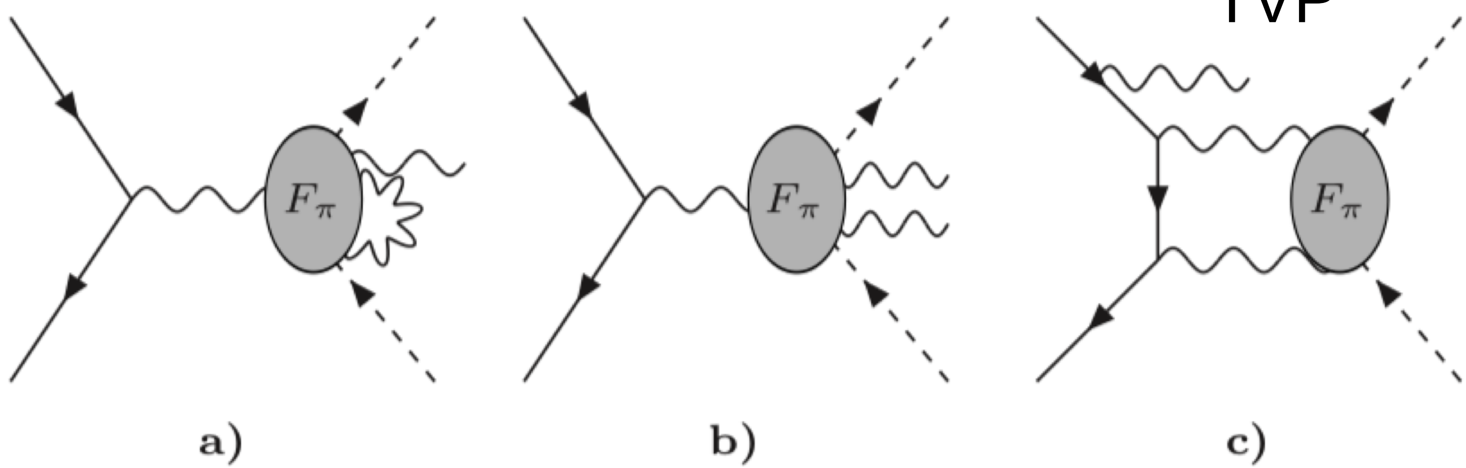
A. Denner et al. Nucl. Phys. B 734 (2006) 62, T. Binoth et al., JHEP 0510 (2005) 015

F. Campanario, JHEP 1110 (2011) 070

F. Campanario et al.
PRD100 (2019) 7, 076004

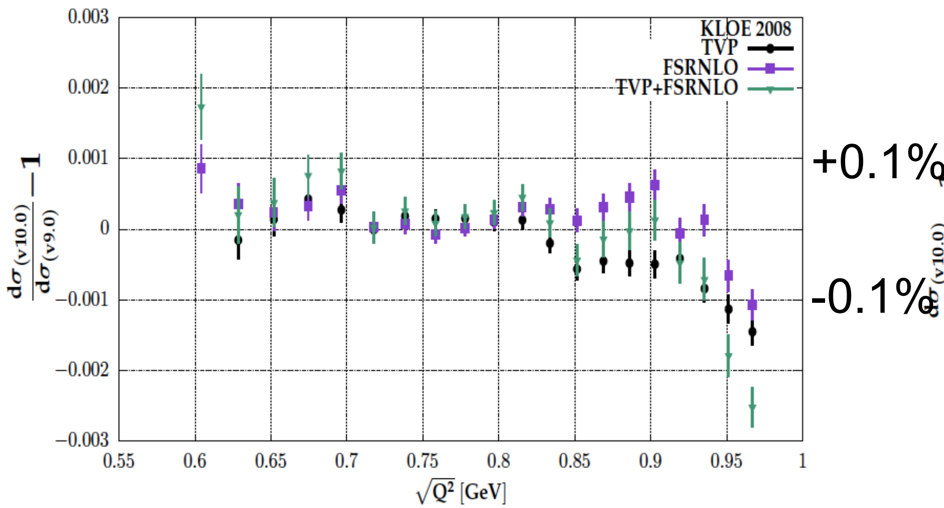
FSRNLO

TVP

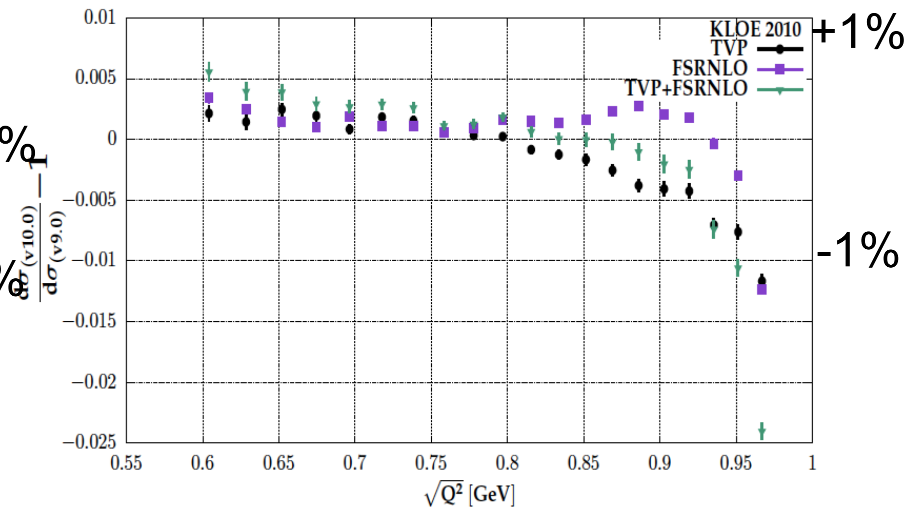


Effect of NLO missing corrections in previous version of PHOKHARA (used by experiments)

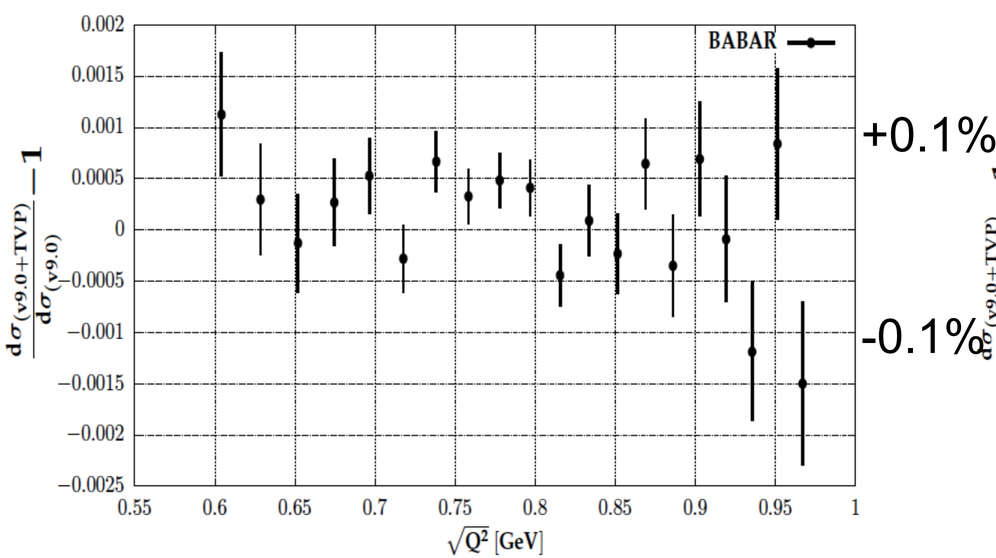
Complete NLO: KLOE-small



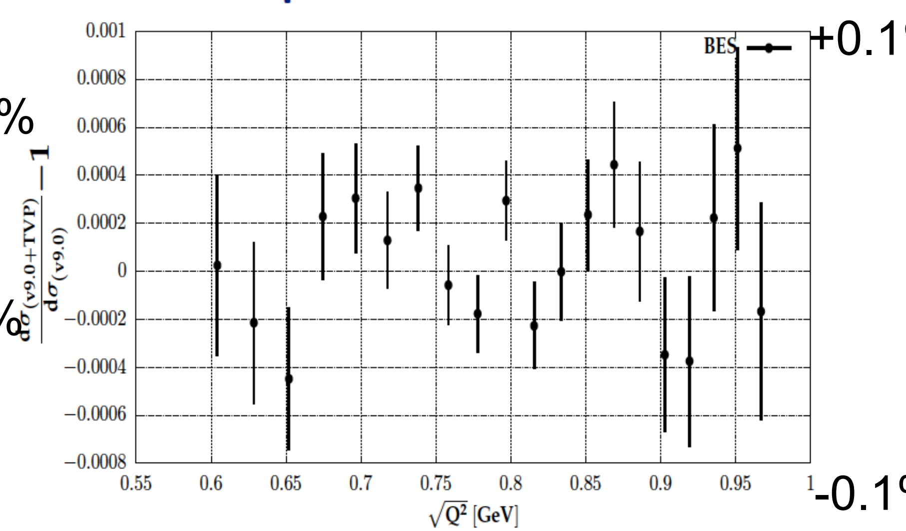
Complete NLO: KLOE-large



Complete NLO: BaBar



Complete NLO: BES



Conclusions

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

show that missing NLO radiative corrections

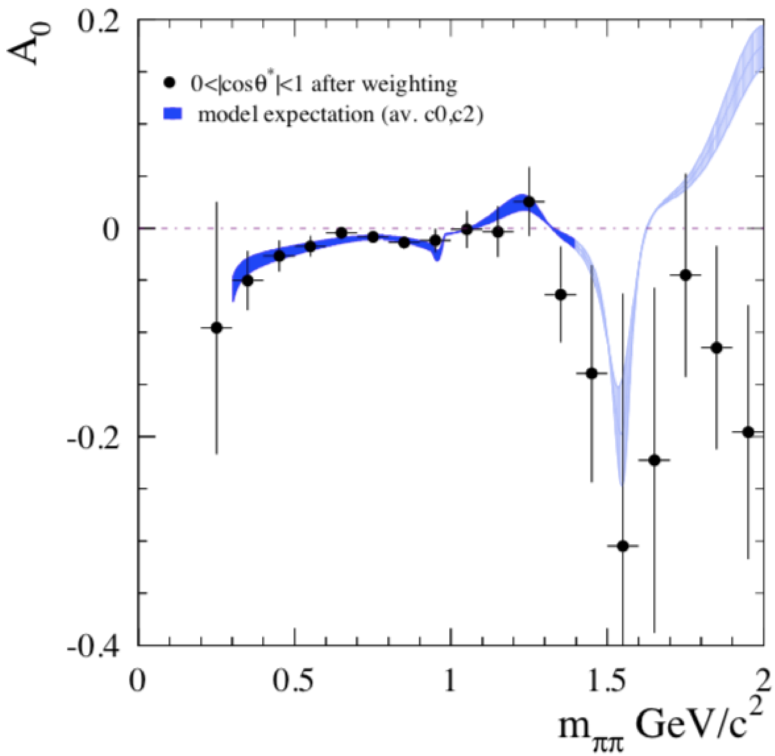
cannot be the source of the discrepancies between

the different extractions of the pion form factor

performed by BaBar, BES and KLOE

Test of FSR model for pions

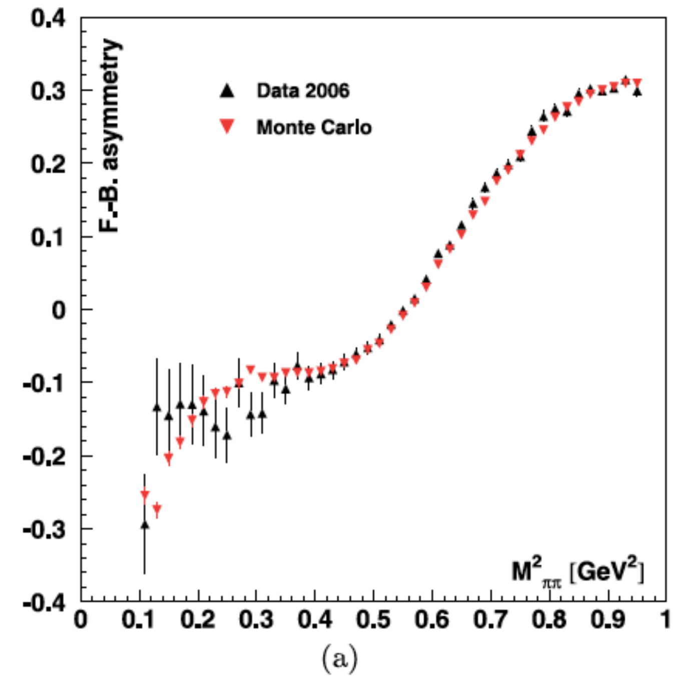
Charge asymmetry



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)

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

PrecisionSM collaborative web site

https://precision-sm.github.io/

PrecisionSM Posts About RSS feed Search

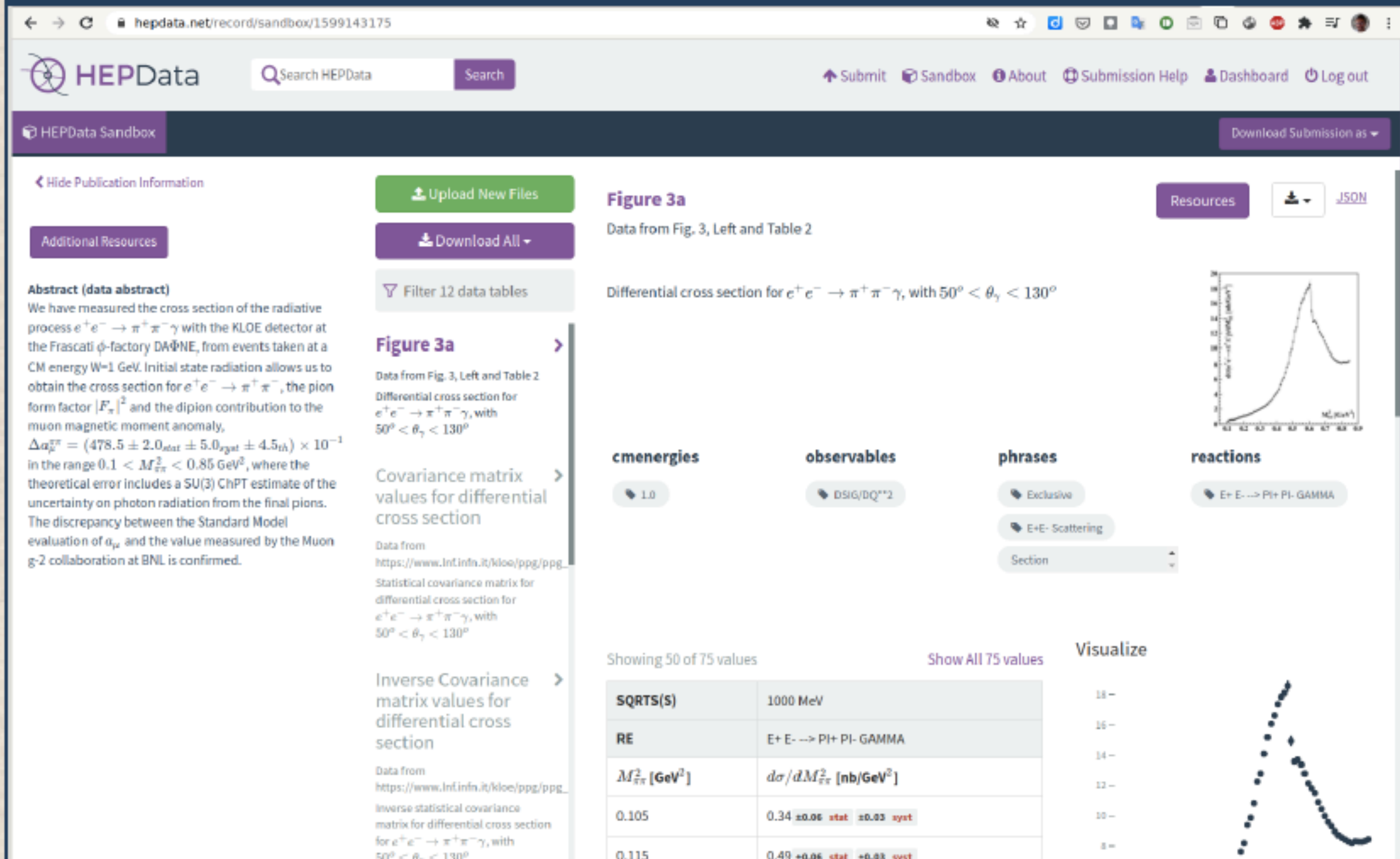
Draft PrecisionSM web site

- Example code to create a responsive plot using results stored in HEPData.net
- Example of responsive plot integrated in this website
- Example notebook
- Fedor Ignatov responsive plots

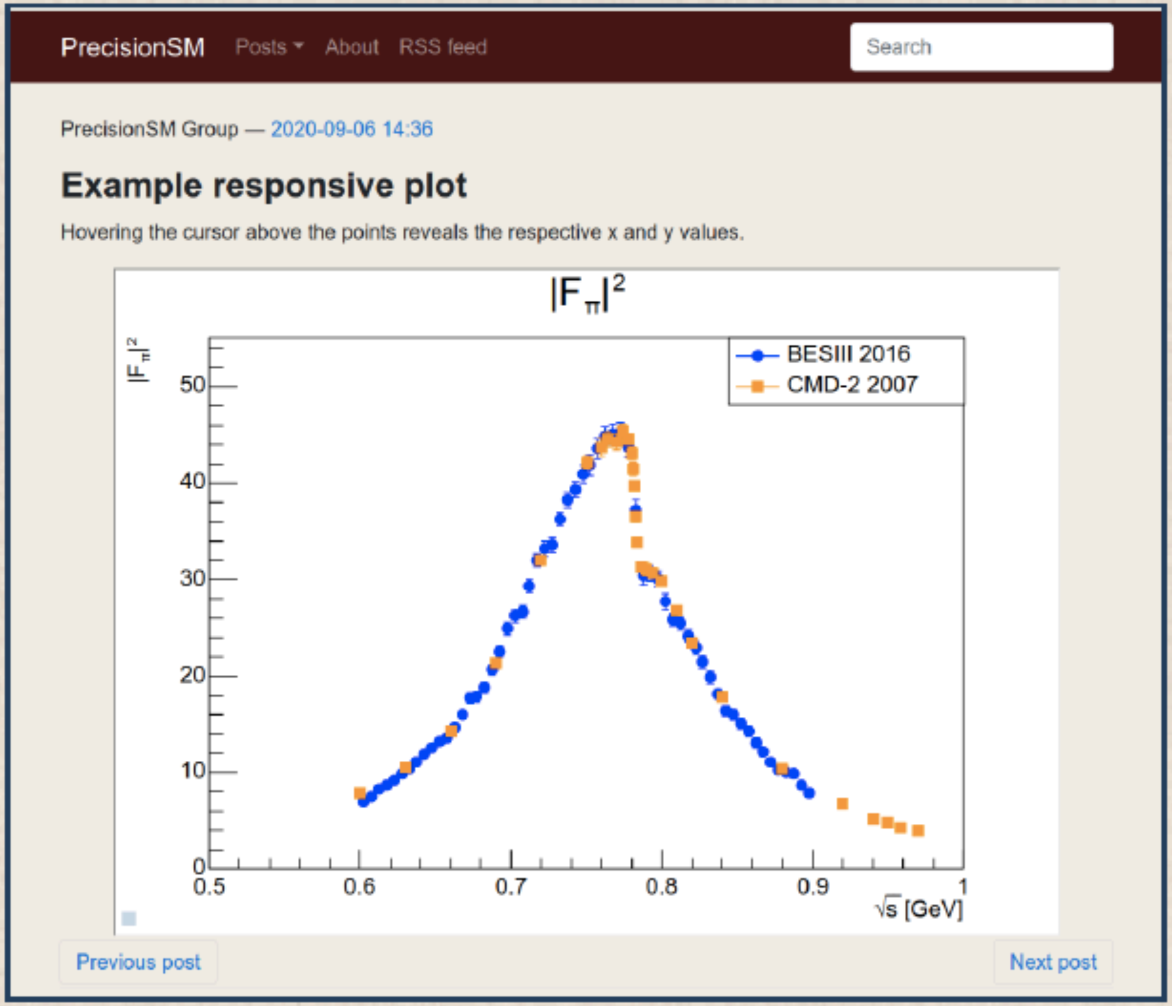
Contents © 2020 PrecisionSM Group - Powered by Nikola

HEPData.net provisional submission of KLOE10 $e^+e^- \to \pi^+\pi^-(\gamma)$

https://www.hepdata.net/record/sandbox/1599143175

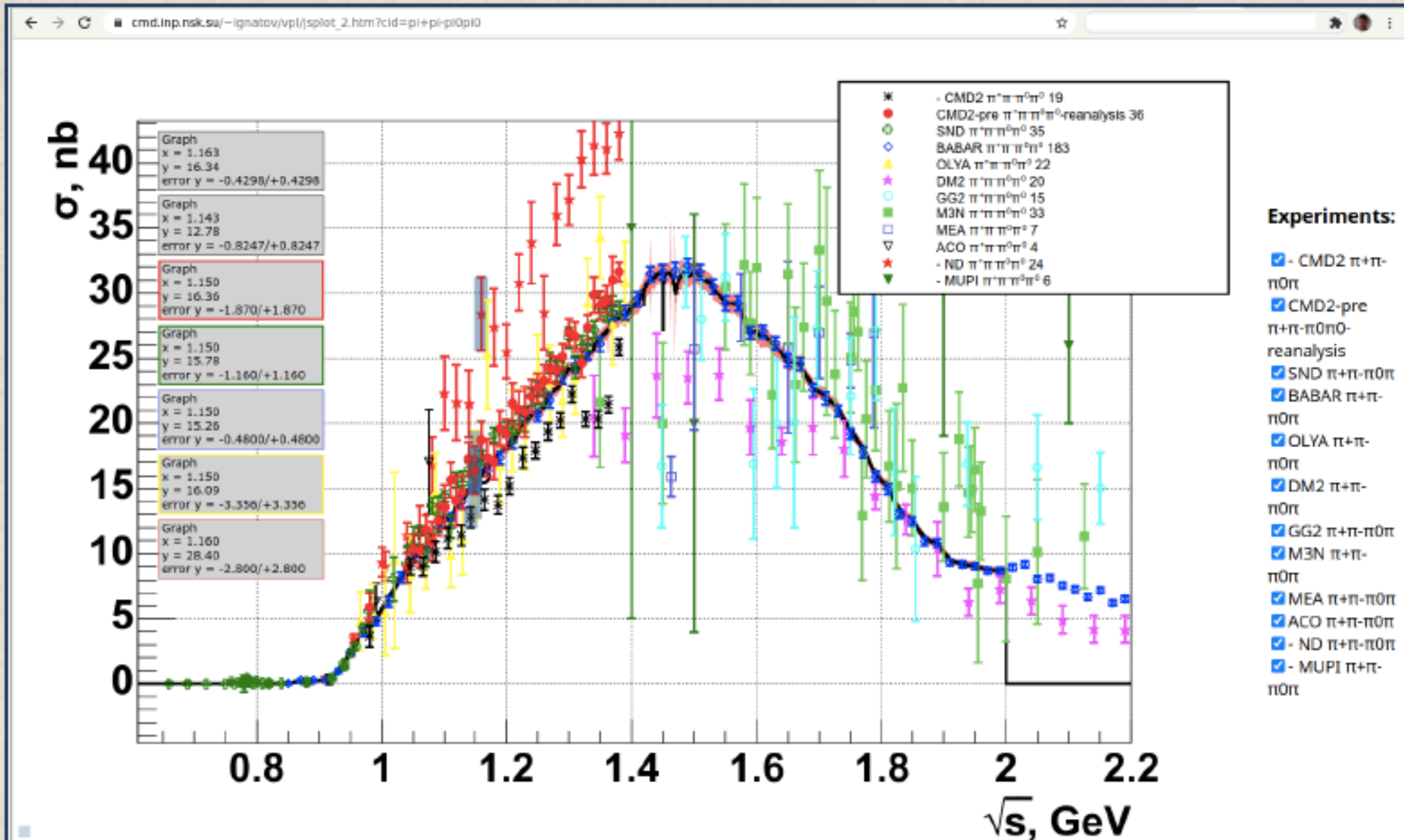


Web site, example of responsive plot



Web site, Fedor Ignatov responsive plot

- re-using (with his collaboration) techniques used by F. Ignatov in https://cmd.inp.nsk.su/~ignatov/vpl/



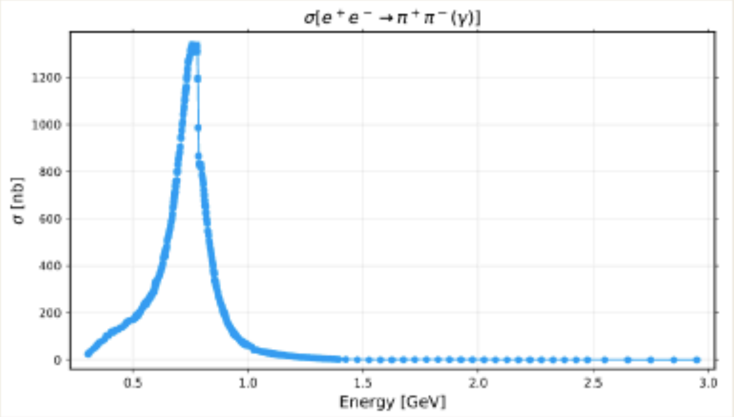
Web site, read BaBar $e^+e^- \to \pi^+\pi^-(\gamma)$ and make plots

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]:

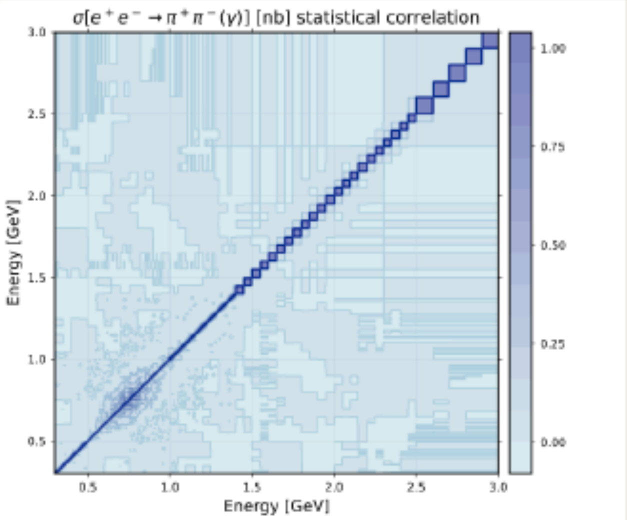


correlation

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]:



Next steps

- responsive plot feature of channel selection (know how to do it, just matter of available time)
- collect list of measurements to be uploaded to HEPData.net
- organize and collaborate with experiments to upload the measurements' data
- produce responsive plots from data uploaded on HEPData.net (semi-automatic)
- document measurements in web site
  - link to HEPData.net, inspirehep, brief description, plots
- organize measurements in categories
- publish example code pieces: data downloading, elaborations

Thanks for your attention!

Next (virtual) meeting: 24-26 November 2021

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.

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

We will discuss all of that! If you are interested you are welcome!

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%
- Radio MonteCarLow activity still important!
- Strong2020 project will contribute with a database for low-energy hadronic cross sections in e+e- collisions.

If you are interested to contribute you are welcome!

END

FSR studies

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"Non-Born"

$$M^{\mu\nu}_{NB}(Q,k,r) = -ie^2(\tau_1^{\mu\nu} f_1^{NB} + \tau_2^{\mu\nu} f_2^{NB} + \tau_3^{\mu\nu} f_3^{NB}),$$

- explicit form of $f^{NB}_{1,2,3}$ is model-dependent

We now work with

- SU(2) and SU(3) Chiral Perturbation Theory
- KLOE model as implemented in PHOKHARA 6.1 and FASTERD by Olga Shekhovtsova [Shekhovtsova, Venanzoni, Pancheri, arXiv:0901.4440 [hep-ph] (2009)]

These models give "predictions" for FSR:
parameters are fixed independently

Using realistic cuts:

FSR studies

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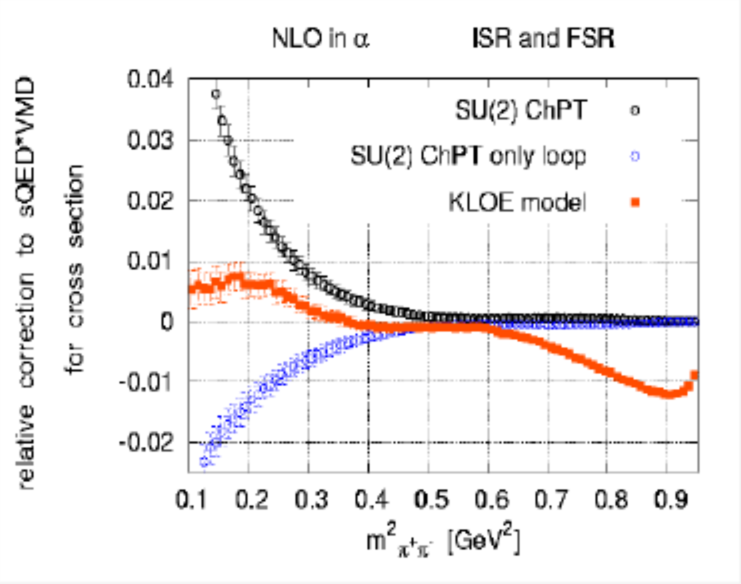
Role of "non-Born" correction



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

$\sqrt{s} = 1$ GeV

$50^o < \theta_\gamma < 130^o$

- model dependence is small
- at KLOE statistics the ChPT-corrections are not visible
- effect is enhanced at low $m_{\pi\pi}$