The STRONG2020 and Radio MonteCarLow activities

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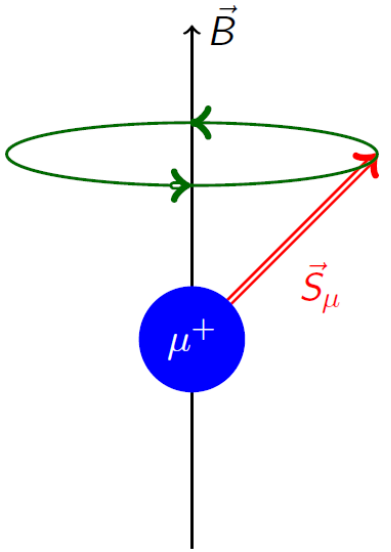
15/05/2023: NEW FRONTIERS IN LEPTON FLAVOR, PISA

Outline

- Current theoretical and experimental a_μ scenario
- Radio MonteCarLow and STRONG2020 activities
- Goal: hadronic e^+e^- database
  - Information we collect
  - Steps to create it
  - Comparative plots available

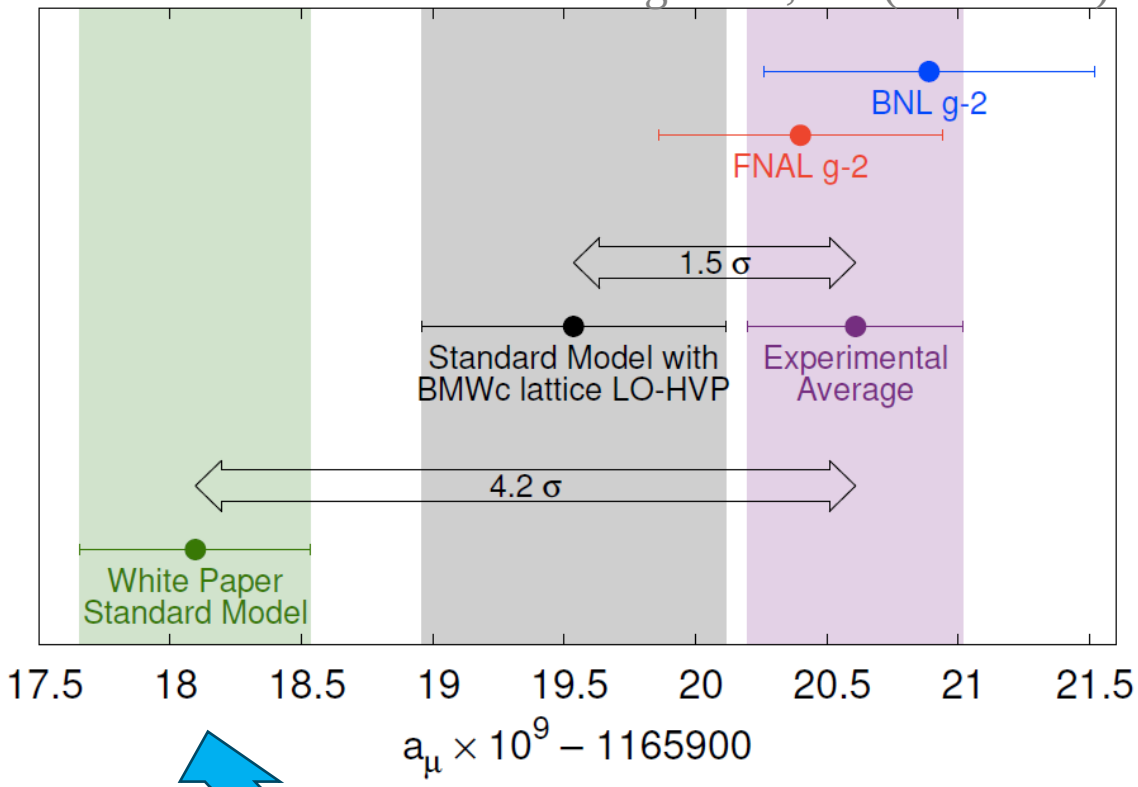


$$\vec{\mu} = g\frac{e}{2m}\vec{S}$$

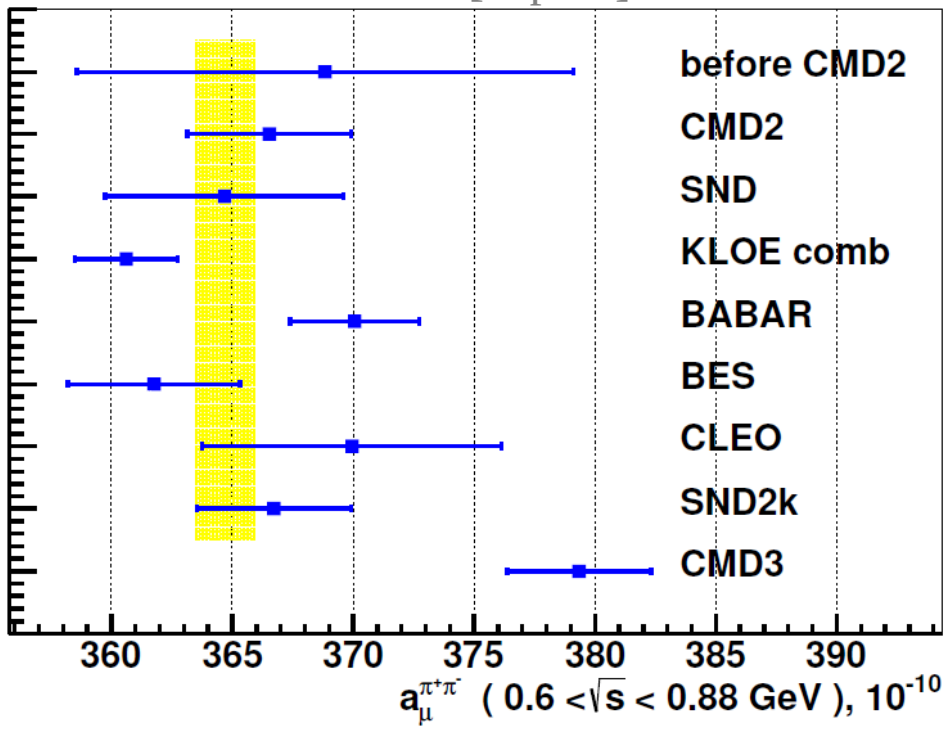
$$a_\mu = \frac{g-2}{2}$$

Muon $g-2$: theory vs experiment

L. Lellouch's slides at SchwingerFest, LA (June 2022)



arXiv:2302.08834v1 [hep-ex] 17 Feb 2023



Hadronic QCD contributions to a_μ from lattice or from data-driven dispersive approach that uses $R(s)$ (input from $e^+e^- \rightarrow hadrons$ experimental data)

Activities on low energy e^+e^- data

QCD accounts for $6 \cdot 10^{-5}$ of a_μ but also for 99.97% of total uncertainty

Radio MonteCarLow WG

- Radiative corrections and Monte Carlo generators for Low energies WG
- Goal: development of best radiative corrections and MC generators for low-energy e^+e^- and τ-decays data
- Active from 2006 to 2019

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

STRONG2020 Project

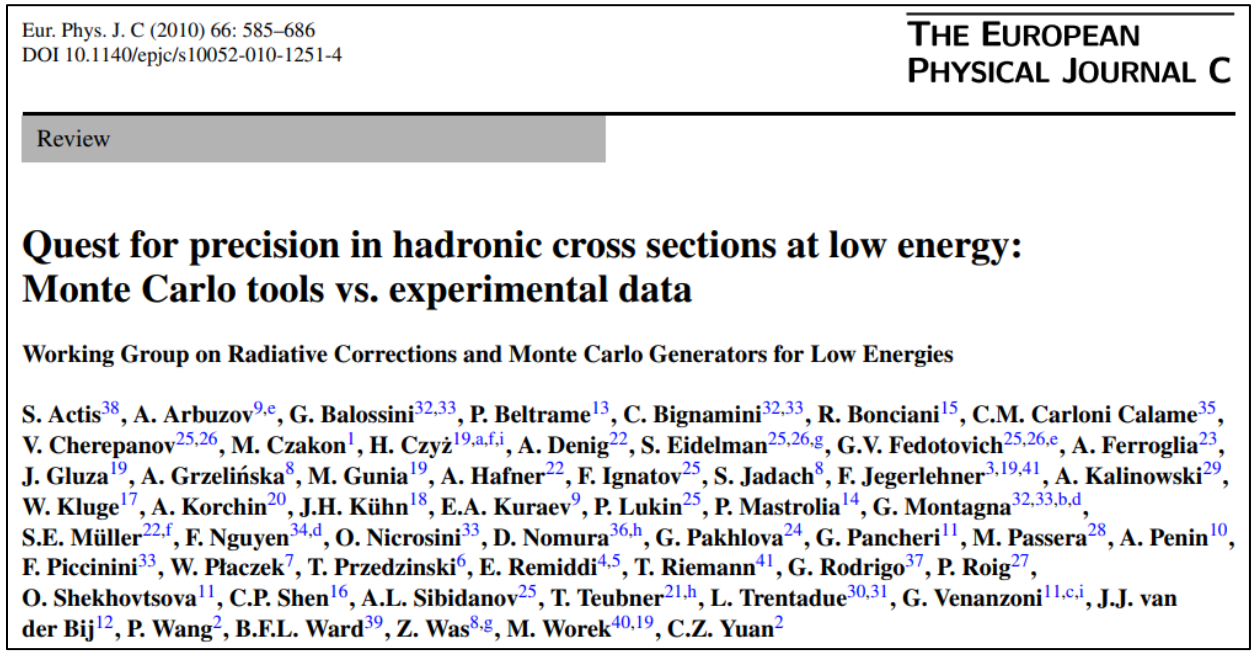
- Work Package under the EU Horizon 2020 grant agreement n. 824093
- Goal: create an annotated database for low-energy hadronic e^+e^-cross sections
- PrecisionSM DB: **precision-sm.github.io**
- Started in 2019

www.strong-2020.eu/

Radio MonteCarLow activities

- 20 meetings between theorists and experimentalists from 2006 to 2019
- Efforts to develop MC generators for luminosity, $e^+e^- \rightarrow$ hadrons + leptons ($+\gamma$ from ISR), τ-lepton production and decays
- Final report, divided into 5 subjects:

1. Luminosity measurements at low energies (up to B-factories energy)
2. R(s) measurement with energy scan
3. R(s) measurement with radiative return
4. τ-lepton physics
5. Calculation of vacuum polarization with emphasis on the hadronic contributions



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 66 (2010) 585-686
More details HERE

Overview of STRONG2020 project

- EU project to study strong interactions
- PrecisionSM "Hadron Physics for Precision Tests of the Standard Model" with several goals:
  - Combine theory and experiment for BSM precision tests (R(s) measurements, Radiative corrections and MC generators)
  - Compile an annotated database for low-energy hadronic cross sections in e^+e^- collisions

- Measurements on HEPData
- Papers on InspireHEP

Dedicated webiste with hyperlinks

Responsive plots of hadronic cross sections

STRONG2020: annotated database (link)

PrecisionSM Contents Docs About RSS feed Search

Low energy e^+e^- channels database

- Measurements Database:
  - $e^+e^- \to \pi^+\pi^-$
- HEPData submissions
  - cured by PrecisionSM
- HEPData submissions checks
- Plots

Contents © 2023 PrecisionSM Group - Powered by Nikola

Input data

Database for $e^+e^- \to \pi^+\pi^-$ channels

Experiment	Year	Reference (link to INSPIRE-HEP)	Link to Hepdata	Details	Status
BESIII (BEPC, Beijing)	2016	Phys.Lett.B 753(2016) 629-638 [errata: Phys.Lett.B 812 (2021) 135982]	ins1385603	details	Finalized
BaBar (SLAC, Stanford U.)	2016	Phys.Rev.D 86 (2012) 032013		details	In Preparation
CLEO (CESR, Cornell U.)	2018	Phys.Rev.D 97 (2018) 3, 032012	ins1643020	details	Finalized
CLEO (CESR, Cornell U.)	2013	Phys.Rev.Lett. 110 (2013) 2, 022002	ins1189656	details	Finalized
CLEOc (CESR, Cornell U.)	2005	Phys.Rev.Lett. 95 (2005) 261803	ins693873	details	Finalized
KLOE (DAPHNE, Frascati)	2017	JHEP 03 (2018) 173		details	In Preparation
KLOE (DAPHNE, Frascati)	2012	Phys.Lett.B 720 (2013) 336-343		details	In

KLOE (DAPHNE, Frascati), 2017

- status: **in preparation**
- hepdata: 1634981
- method: Direct
- quotes:
  - $d\sigma/dQ^2(\pi^+\pi^-\gamma)$ (stat, syst)
  - $\sigma_{\pi^+\pi^-}$ (stat, syst)
  - F_π (stat, syst)
- energy[GeV]: 0.32 - 0.97
- radiative corrections:
  - VP corr. updated to 'alphaQED16.tar.gz' package by F. Jegerlehner (2016)
  - Remaining are in inspirehep-797438, inspirehep-859660, inspirehep-1208095
- comment:
  - combination of KLOE08, KLOE10 and KLOE12 data;
  - updates for inspirehep-797438, inspirehep-859660, inspirehep-1208095

Annotate:

- available data
- energy ranges
- treatment of RC
- …

Main work by A. Driutti, A. Lusiani and LC

Currently reviewing $e^+e^- \to \pi^+\pi^-$

Steps to create the database

1. **DATA COLLECTION**: inputs of hadronic (starting from $\pi^+\pi^-$) e^+e^- data from published experiments (see next slide)

InspireHEP.net

2. **UPLOAD DATA IN PUBLIC REPOSITORY** → HEPData.net

- Collaboration point-of-contact (or STRONG2020 coordinator) submits data

- Reviewer appointed for cross-checks: no mistakes, HEPData.net prescriptions

- If validated: data is posted, can be catalogued and used

3. **CATALOGUE DATA IN ACCESSIBLE WAY**: precision-sm.github.io

- Website files on GitHub

- Created with Nikola static website generator

4. **PROVIDE TOOLS TO ELABORATE DATA** (see following slides)

List of available e^+e^- data

- Collected $e^+e^- \to \pi^+\pi^-$ channel for now. Experiments/Points-of-contact:

➢BaBar / A. Lusiani, B. Malaescu

➢BESIII / A. Denig, C. Redmer

➢KLOE / S. Mueller

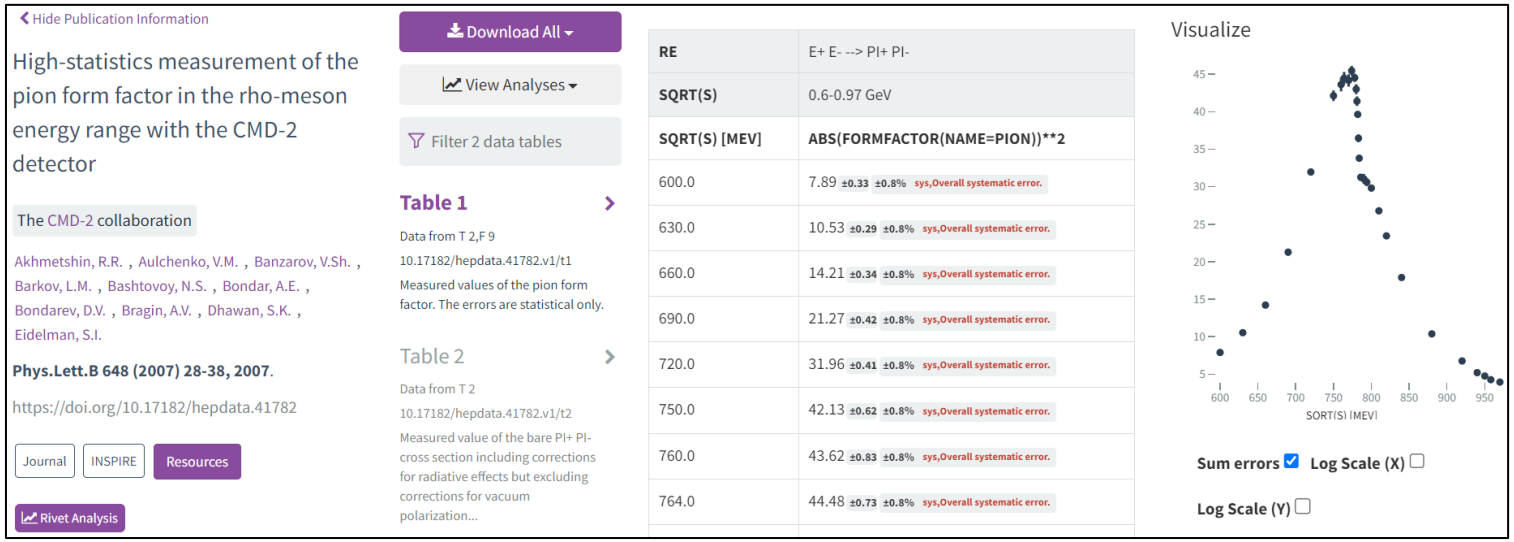
➢Novosibirsk / F. Ignatov, M. Achasov (CMD-2, OLYA, CMD, TOF, VEPP, SND)

➢CLEO / G. Venanzoni

➢ADONE / G. Venanzoni (BCF, MEA)

➢Orsay / G. Venanzoni (DM-1, DM-2, ACO)

➢CERN-NA007

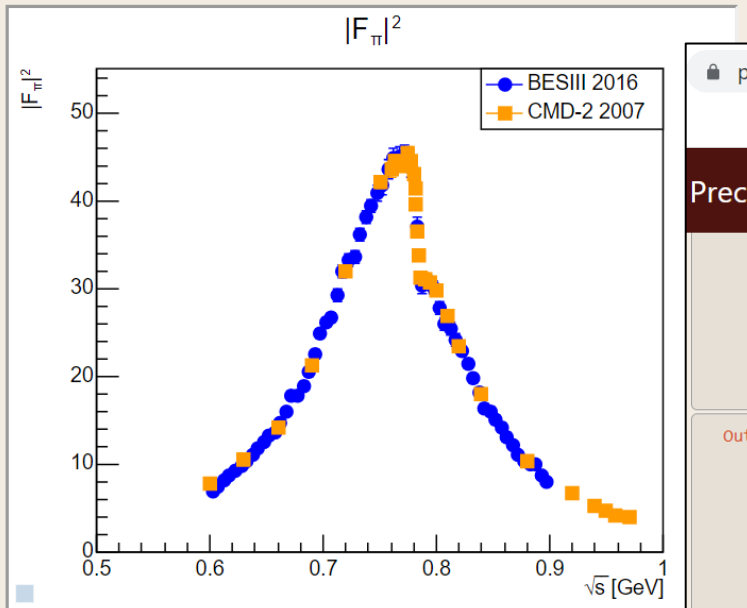


Some of them are **finalized**, others are **in preparation** (inserted on HEPData.net)

STRONG2020 coordinators and reviewers:
A. Driutti, A. Lusiani

Examples of notebooks and responsive plots

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

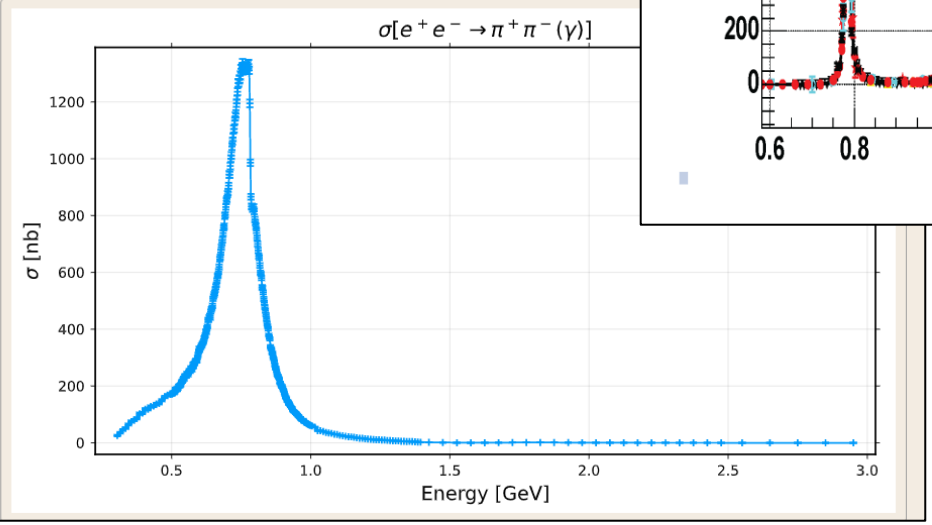


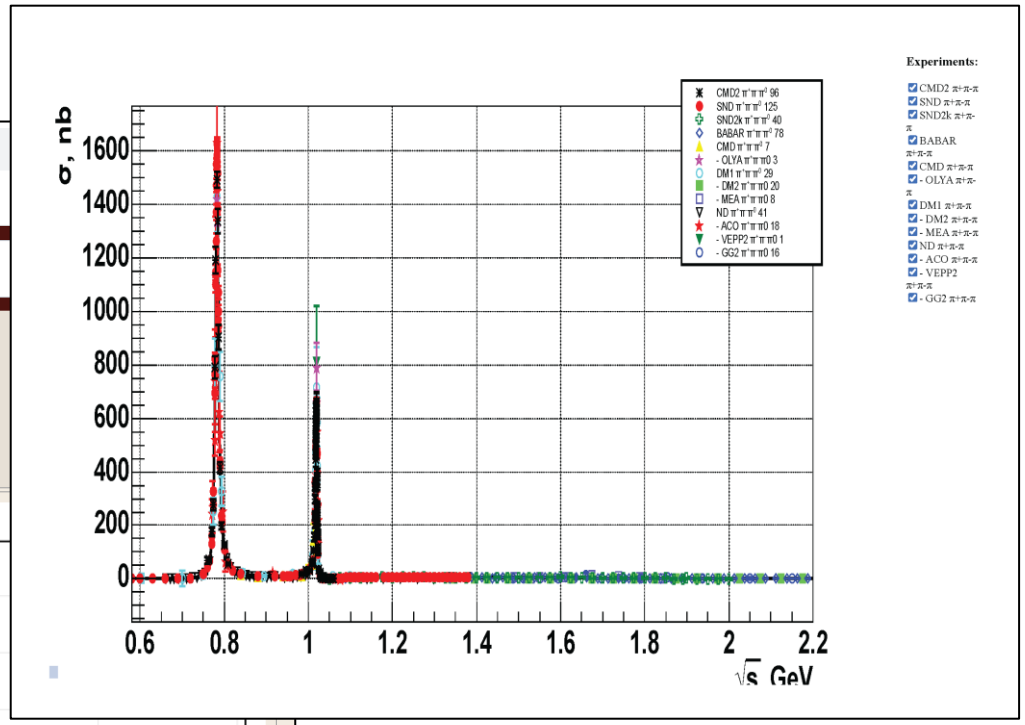
precision-sm.github.io/posts/plot-babar-2012-pip-pim/

PrecisionSM Contents Docs About RSS feed Search

```
  ylabel = L"$\sigma$ [nb]",
  markerstrokecolor = :auto,
  legend = false
)
## mysavefig(curpl, "curpl.pdf")
## display(curpl)
```

Out[16]:





Summary, conclusion and acknowledgements

- Efforts for more than 20 years to improve MC and RC of e^+e^- at low energies
- Radio MonteCarLow activities still important for evaluating a_μ, HVP-LO
- STRONG2020 is contributing with a database for low-energy hadronic cross sections with relevant information (RC treatment, systematic errors, …)
- Stay tuned for updates on https://precision-sm.github.io/!
- This work was supported by the European Union STRONG2020 project under Grant Agreement Number 824093
- We thank the Points-of-Contact of the experiments who are helping us very much!!

THANK YOU VERY MUCH FOR YOUR ATTENTION!

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LARGO BRUNO PONTECORVO 3/BUILDING C, ROOM 192, PISA

BACKUP SLIDES

CMD-3

Questions

- Why CMD-3 result is so different from others?
  We don't know…
- Do we use new method?
  No, it is exactly the same as for CMD-2 and SND, but more statistics (systematics studies) and better detector
- Is there problem with angle measurement (fiducial volume)?
  Unlikely: two systems, asymmetry, angle distribution
- Is there problem with RC calculation?
  Unlikely: CMD-2 and SND uses the same code; asymmetry. But it is a showstopper for better precision. And there could be potential systematic shift in RC for pions (due to limitations of sQED).
- Is there problem with event separation?
  Unlikely: three methods agree (the first measurement with several methods)
- Is there problem with trigger?
  Unlikely: should lead to shift of $\sigma(\mu\mu)$.
- Stupid mistake?
  Always possible, but we've done the whole analysis on MC data