



# Status of Strong2020 activity for a database of $e^+e^-$ into hadrons

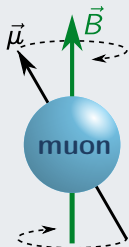
**Alberto Lusiani**  
Scuola Normale Superiore and INFN, sezione di Pisa



Muon Precision Physics Workshop, 7-9 November 2022, The Spine, Liverpool, UK

## Introduction

## Muon spin precession

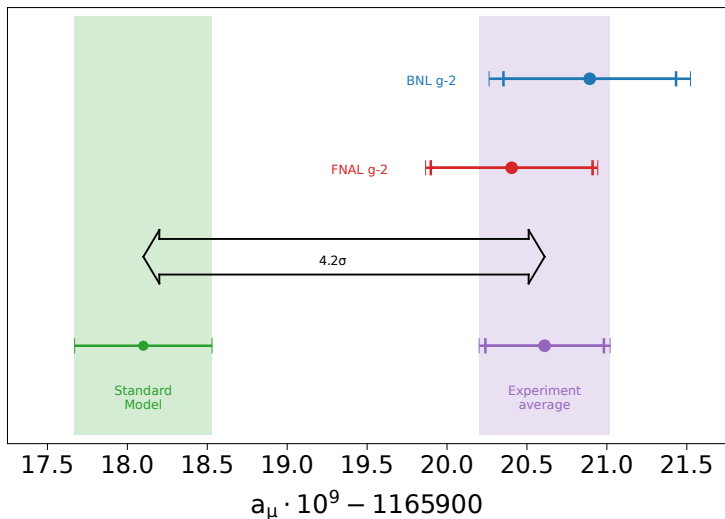
Muon  $g-2$  anomaly

$$a_{\mu}^{\text{exp}} - a_{\mu}^{\text{th}} = +251(59) \cdot 10^{-11}$$

$$\Delta a_{\mu}^{\text{exp}} = 41 \cdot 10^{-11}$$

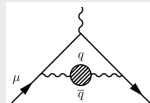
$$\Delta a_{\mu}^{\text{th}} = 43 \cdot 10^{-11}$$

## Muon magnetic anomaly discrepancy, April 2021



# Introduction

$$\Delta a_\mu^{\text{th}} \times 10^{11} = 43 = 40(\text{HVP,LO})(\dots)$$



$a_\mu^{\text{HVP,LO}}$  computation

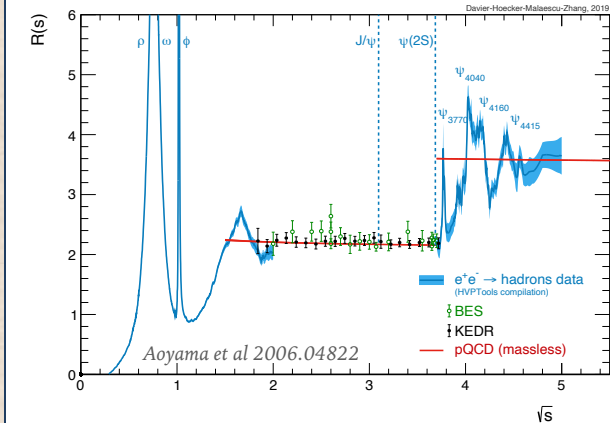
$$a_\mu^{\text{HVP,LO}} = \left(\frac{\alpha m_\mu}{3\pi}\right)^2 \int_{m_\pi^2}^{\infty} \frac{\hat{K}(s)}{s^2} R(s) ds$$

$$R(s) = \frac{\sigma^0(e^+e^- \rightarrow \text{hadrons}(\gamma))(s)}{\sigma^0(e^+e^- \rightarrow \mu^+\mu^-(\gamma))(s)}$$

cross sections  $\sigma^0(\dots(\gamma))$

- ▶ inclusive of higher order radiative processes
- ▶ subtracted of HVP contribution to photon propagator
- ▶  $\Delta a_\mu^{\text{HVP,LO}} = 0.57\%$  now  
but 0.23% desirable in near future to match experimental precision

$R(s)$  as measured by experiments



## Strong 2020 / PrecisionSM

### Strong-2020

- ▶ EU Horizon 2020 grant agreement n. 824093



“The strong interaction at the frontier of knowledge: fundamental research and applications”

<http://www.strong-2020.eu/>

### PrecisionSM

- ▶ Strong-2020 Work Package 21, RA3-**PrecisionSM**: “Precision Tests of the Standard Model”
  - ▶ goal: annotated database for low-energy hadronic cross sections in  $e^+e^-$  collisions, started in 2019
  - ▶ coordinators: Andrzej Kupsc, Graziano Venanzoni
  - ▶ work-in-progress web site: <https://precision-sm.github.io/>

## Strong 2020 / PrecisionSM plans

- ▶ publish on web **annotated database of hadronic cross-section measurements** for computation of the HVP,LO contribution to muon magnetic anomaly
- ▶ rely on  **$\sigma(e^+e^- \rightarrow \text{hadrons})$  measurements** HEPData records
  - ▶ links to HEPData records
  - ▶ group measurements in categories
  - ▶ use tags to label useful properties
  - ▶ responsive plots of hadronic cross-sections, **relying on work by Fedor Ignatov**
  - ▶ documentation and code examples on how to use HEPData records
- ▶ prepare collaborative framework for ultimate goals such as full open-source calculation of  $a_\mu^{\text{HVP,LO}}$

HEPData, funded by a UK STFC grant, based at IPPP, Durham University



**Graeme Watt**

IPPP, Durham University  
Project Manager (2013-)



**Michael Spannowsky**

IPPP, Durham University  
Principal Investigator (2019-)



## HEPData.net

- ▶ HEP data public storage web site, mainly used by LHC experiments
- ▶ well defined submission data format, functionally adequate for our data of interest
- ▶ uses YAML and JSON, can export to Root format and other formats
- ▶ measurements on [HEPData.net](https://hepdata.net) link their [InspireHEP.net](https://inspirehep.net) publication and [InspireHEP.net](https://inspirehep.net) back-links [HEPData.net](https://hepdata.net)
- ▶ possible to download data and metadata programmatically
- ▶ submissions are done by authorized contact persons of collaborations
  - ▶ higher quality and reliability than first phase submissions done by just HEPData personnel
- ▶ some experiments (mainly LHC ones) quite active in promptly uploading their published data

# HEPData, example of stored hadronic cross-section measurement

**HEPData** Search HEPData Search About Submission Help File Formats Sign in

Browse all Benaksas, D. et al. Last updated on 1979-07-17 00:00 LAL Accessed 584 times Cite JSON

Hide Publication Information

**pi+ pi- production by e+ e- annihilation in the rho energy range with the Orsay storage ring**

Benaksas, D., Cosme, G., Jean-Marie, B., Jullian, S., Laplanche, F., Lefrancois, J., Liberman, A.D., Parrou, G., Repellin, J.P., Sauvage, G.

**Phys.Lett.B 39 (1972) 289-293, 1972.**  
<https://doi.org/10.17182/hepdata.28321>

Journal INSPIRE

**Abstract (data abstract)**  
 ORSAY-ACO, 60 PCT SOLID ANGLE DETECTOR. RHO-OMEGA INTERFERENCE MEASURED. THESE DATA ARE INCOMPATIBLE WITH PREVIOUS ORSAY RESULTS, J. E. AUGUSTIN ET AL., NCL2, 214 (1969).

**Table 1** [10.17182/hepdata.28321.v1.t1](#)  
 Data from T 2

STATISTICAL ERRORS ONLY. CROSS SECTION AT RHO0 PEAK IS  $1.00 \pm 0.13$  MUB FROM FIT.

Download All Filter 1 data tables

**Table 1** Data from T 2  
 10.17182/hepdata.28321.v1.t1  
 STATISTICAL ERRORS ONLY. CROSS SECTION AT RHO0 PEAK IS  $1.00 \pm 0.13$  MUB FROM FIT.

**cmenergies** 0.705-0.99

**observables** SIG

**phrases** Integrated Cross Cross Section E+ E- Scattering

**reactions** E+ E- -> Pi+ Pi- E+ E- -> RHO0

RE	E+ E- -> Pi+ Pi-
<b>SQRT(S)</b>	0.705-0.99 GeV
<b>SQRT(S) [GEV]</b>	<b>SIG [MUB]</b>
0.705	0.77 ±0.08
0.758	1.09 ±0.11
0.7714	1.12 ±0.1
0.7777	1.22 ±0.1
0.784	1.02 ±0.07
0.7903	0.73 ±0.06
0.7967	0.69 ±0.1
0.8099	0.62 ±0.08

**Visualize**

Sum errors  Log Scale (X)

Log Scale: 0.0

IP3 Durham University CERN UK Science and Technology Facilities Council



## Campaign to submit existing measurements to HEPData

- ▶ large amount of  $\sigma(e^+e^- \rightarrow \text{hadrons})$  measurements published, but not in HEPData
- ▶ most old or non-operative collaborations do not have a HEPData submission coordinator
- ▶ PrecisionSM coordinates & collaborates to submission of published measurements, (starting with  $\sigma[e^+e^- \rightarrow \pi^+\pi^-(\gamma)]$ )
- ▶ HEPData authorized a PrecisionSM submission coordinator (A.L.)

### HEPData submission

- ▶ experimental collaboration nominates submission coordinator
- ▶ for each measurement, coordinator appoints & authorizes submission uploader and submission reviewer
- ▶ HEPData web site
  - ▶ provides forms for authorized uploading of data and meta-data
  - ▶ checks data and presents draft publication of uploaded information
  - ▶ handles review and publication approval steps

## Campaign to submit existing measurements to HEPData

### uploaders and reviewers involved so far in PrecisionSM submissions

	uploader	reviewer
Novosibirsk experiments	Fedor V. Ignatov	Fedor V. Ignatov
-	Fedor V. Ignatov	Boris A. Shwartz
-	Fedor V. Ignatov	Gennadiy V. Fedotovitch
-	Michail Achasov	Fedor V. Ignatov
BaBar	A.L.	Bogdan Malaescu
KLOE	Stefan Mueller	Graziano Venanzoni
BES III	BES III appointed	BES III appointed
CLEO	Sean Dobbs	Sean Dobbs

## PrecisionSM, measurement database in YAML text file

- ▶ standard text format for numeric and text data
- ▶ easy to edit manually
- ▶ easily “versioned” in git repository
- ▶ easily read/write in Python, C++, etc.
- ▶ programmatically converted to web pages

## example measurement entry in YAML DB

```

inspirehep-100180:
  channel: $\pi^+\pi^-$
  experiment: BCF (ADONE, Frascati)
  year: 1975
  reference: https://inspirehep.net/literature/100180
  inspirehep: '100180'
  hepdata: ins100180
  method: Direct
  quotes:
  - - $F_\pi$
    - tot
    - stat
    - syst
  E_lo: 1.44
  E_hi: 9.0
  rad_corr:
  - No Mention
  comment:
  - Uncertainties are not disaggregated

```

PrecisionSM website at <https://precision-sm.github.io/>

PrecisionSM Contents ▾ Docs About ▾ RSS feed

Search



## PrecisionSM web site (work in progress)

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



Contents © 2022 PrecisionSM Group - Powered by Nikola

- ▶ adaptive to browser width, readable also on cell phones
- ▶ static web pages, incrementally compiled when source updated
- ▶ searchable, does not store cookies

## PrecisionSM website display of annotated DB (work-in-progress)

The image displays three screenshots of the PrecisionSM website, illustrating the structure of the annotated database.

**Top Screenshot: PrecisionSM web site (work in progress)**

- Navigation: Contents, Docs, About, RSS feed
- Search bar
- Section: PrecisionSM web site (work in progress)
- Menu:
  - Measurements Database
  - HEPData submissions
    - cured by PrecisionSM
  - HEPData submissions checks
  - Plots
- Logo: STRONG 2020 (with European Union flag)
- Footer: Contents © 2022 PrecisionSM Group - Powered by Nikola

**Middle Screenshot: Measurements Database**

(download)

channel	experiment	year	ref	hepdata	details
$\pi^+\pi^-$	BCF (ADONE, Frascati)	1975	<a href="#">ref</a>	<a href="#">hepdata</a>	<a href="#">details</a>
$\pi^+\pi^-$	MEA (ADONE, Frascati)	1977	<a href="#">ref</a>	<a href="#">hepdata</a>	<a href="#">details</a>
$\pi^+\pi^-$	MEA (ADONE, Frascati)	1980	<a href="#">ref</a>	<a href="#">hepdata</a>	<a href="#">details</a>
$\pi^+\pi^-$	CLEOc (CESR, Cornell)	2005	<a href="#">ref</a>		<a href="#">details</a>
$\pi^+\pi^-$	CLEOc (CESR, Cornell)	2013	<a href="#">ref</a>		<a href="#">details</a>
$\pi^+\pi^-$	CLEOc (CESR, Cornell)	2018	<a href="#">ref</a>		<a href="#">details</a>
$\pi^+\pi^-$	ACO (Orsay)	1972	<a href="#">ref</a>	<a href="#">hepdata</a>	<a href="#">details</a>
$\pi^+\pi^-$	ACO (Orsay)	1976	<a href="#">ref</a>	<a href="#">hepdata</a>	<a href="#">details</a>
$\pi^+\pi^-$	NAT (Fixed target, CERN)	1984	<a href="#">ref</a>	<a href="#">hepdata</a>	<a href="#">details</a>

**Bottom Screenshot: Detailed view of  $\pi^+\pi^-$ , BCF (ADONE, Frascati), 1975**

- hepdata: ins100180
- method: Direct
- quotes:  $F_\pi$
- energy [GeV]: 1.44 - 9
- rad\_corr:
  - No Mention
- comment:
  - Errors not divided

## PrecisionSM web site, responsive plot

PrecisionSM Contents Docs About RSS feed

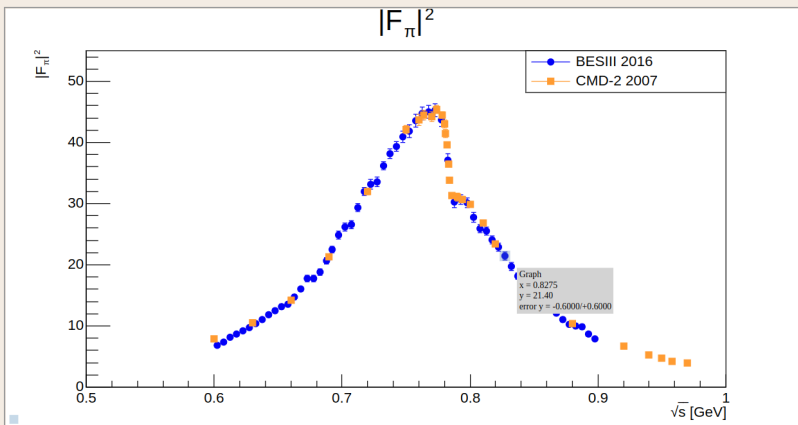
Search



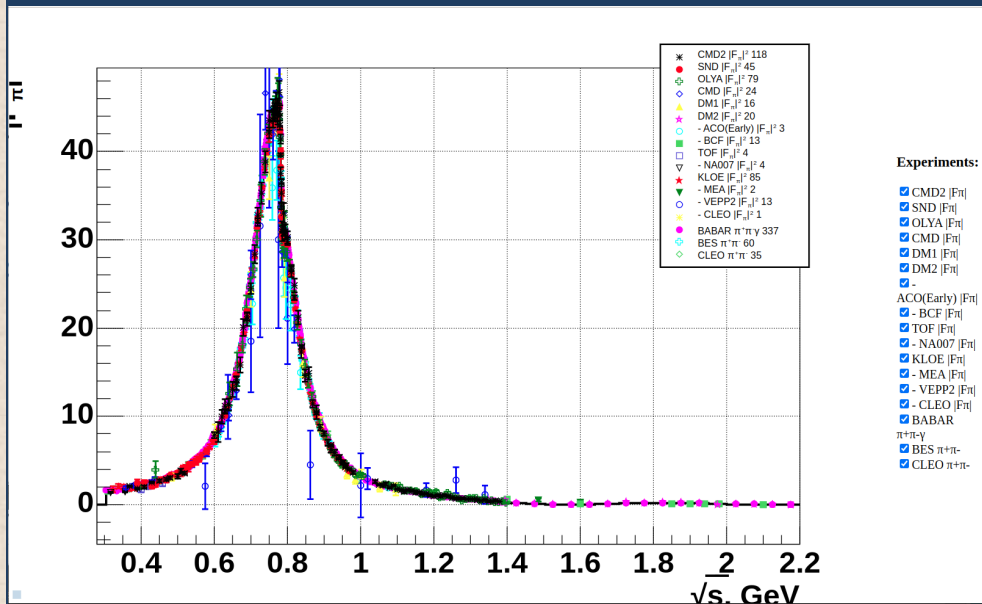
## Example display responsive plots

PrecisionSM Group — 2020-09-06 14:36

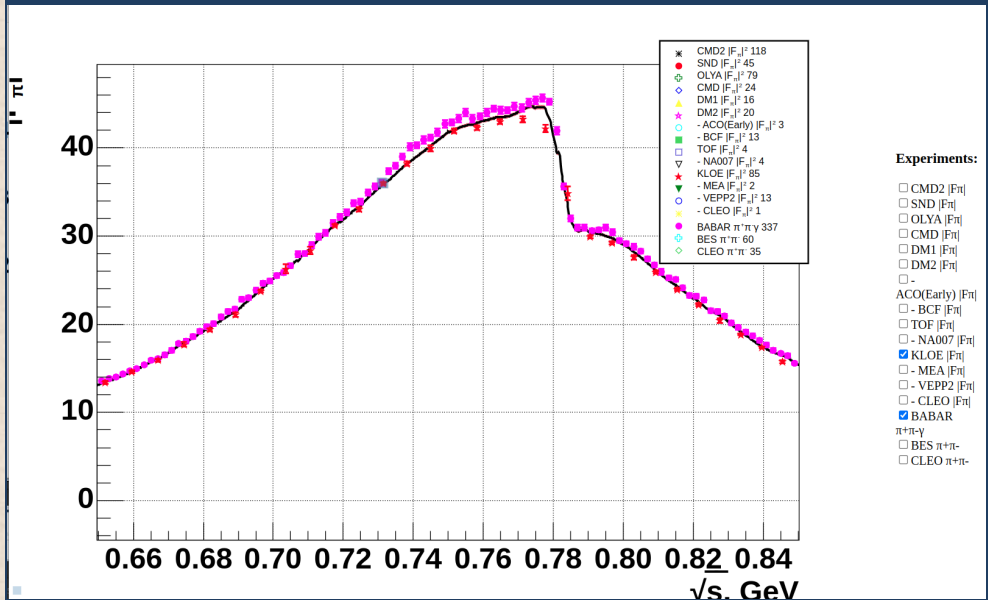
Hovering the cursor above the points reveals the respective x and y values.

[Previous post](#)[Next post](#)

## PrecisionSM web site, responsive plot (2)

 $\sigma[e^+e^- \rightarrow \pi^+\pi^-(\gamma)]$ , by Fedor Ignatov, imported to PrecisionSM web site

## PrecisionSM web site, responsive plot (3)

 $\sigma[e^+e^- \rightarrow \pi^+\pi^-(\gamma)]$ , by Fedor Ignatov, imported to PrecisionSM web site



## PrecisionSM web site, read HEPData measurements &amp; prepare responsive plot

PrecisionSM Posts About RSS feed Search

## Prepare Root Plot with data from HEPData

PrecisionSM Group — 2020-11-21 01:05

**get two cross-section measurements from HEPData and plot them**

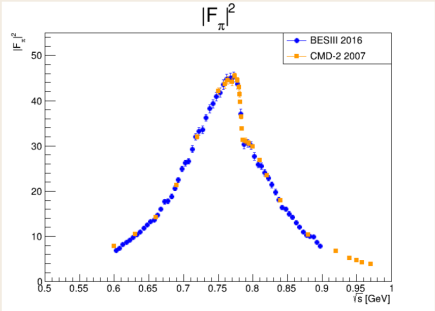
- $e^+e^- \rightarrow \pi^+\pi^-$  BES-III 2016 <https://www.hepdata.net/record/ins1385603>
- $e^+e^- \rightarrow \pi^+\pi^-$  CMD-2 2007 <https://www.hepdata.net/record/ins728302>

```
In [1]: from math import *
import re
from pprint import pprint
import urllib.request
from requests.utils import requote_uri
from array import array
import json
import yaml
import itertools
import ROOT
from ROOT import TCanvas, TFile, TProfile, TTuple, TH1F, TH2F, TLegend
from ROOT import TGraph, TGraphErrors, TGraphAsymmErrors
from ROOT import gROOT, gBenchmark, gRandom, gSystem, gStyle, gPad

Welcome to Jupyter 6.22/08
```

```
In [2]: ##
## iterator generator using outer product of two lists
## - first list is inner and second one is outer
## - also able to return nth elements of iterator
## - iterator never ends but folds
##
class iterprod2:
    def __init__(self, arr1, arr2):
        self.arr1, self.arr2 = arr1, arr2
    def __iter__(self):
        self.i1 = 0
        self.i2 = 0
        return self
    def next(self):
```

```
In [15]: leg = TLegend(0.65, 0.80, 0.90, 0.90)
leg.SetFontSize(0.835)
leg.AddEntry(Ins1385603_gr, Ins1385603_gr.GetTitle(), "LP")
leg.AddEntry(Ins728302_gr, Ins728302_gr.GetTitle(), "LP")
leg.Draw()
canvas.Draw()
```

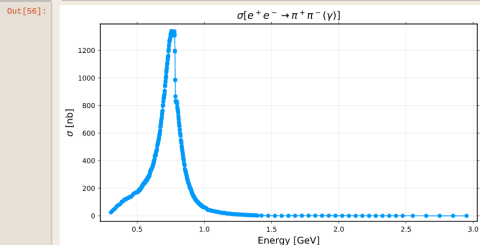


```
In [16]: rfile = TFile("precsm-resp-plot-example.root", "recreate")
canvas.Write("F_pip_pi0")
rfile.Close()
```

PrecisionSM web site, read BaBar  $e^+e^- \rightarrow \pi^+\pi^-(\gamma)$  and make plots

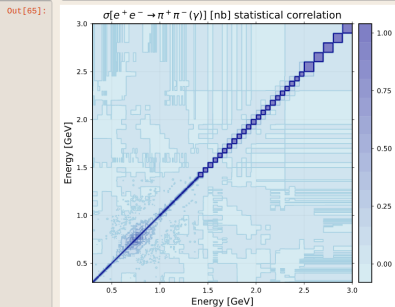
## cross-section

```
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)
```



## 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,
    ## cims = sigma_stat_corr_cims,
    color = :blues,
    title=L"$\sigma[e^+e^- \rightarrow \pi^+\pi^-(\gamma)]$ [nb] statistical correlation",
    xlabel="Energy [GeV]",
    ylabel="Energy [GeV]",
    size=(600, 500)
)
```



## PrecisionSM web site: collaborative framework on github.com

- ▶ measurement data base and source web site files on Github repository
- ▶ Nikola static web generator generates website (= HTML, CSS and javascript)
- ▶ simple procedure to publish on Github Pages at <https://precision-sm.github.io/>
- ▶ web pages are edited in simplified markup languages like Markdown
  - ▶ but HTML, CSS and Javascript can be used if desired
- ▶ collaborators can be added as editors of Github repository
- ▶ git repository keeps tracks of all changes and resolves editing conflicts
- ▶ Anna Driutti in Pisa has started collaborating

## PrecisionSM workshop in November 2021

<https://agenda.infn.it/event/28089/> (proceedings [arXiv:2201.12102](https://arxiv.org/abs/2201.12102) [[hep-ph](#)]).

The screenshot shows the event page for the STRONG2020 Virtual Workshop. The header features the event logo, which includes the text 'STRONG' in blue and '2020' in white with a European Union flag motif. The main title is 'STRONG 2020 Virtual Workshop on "Spacelike and Timelike determination of the Hadronic Leading Order contribution to the Muon g-2"'. The event dates are 'Nov 24 – 26, 2021' in the 'Europe/Rome' timezone. A search bar is present with the placeholder 'Enter your search term'. A left sidebar contains a navigation menu with the following items: Overview (selected), Scientific Program, Call for Abstracts, Timetable, Contribution List, Book of Abstracts, Registration, Participant List, Program committee, and Proceedings. The main content area contains a description: '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.' Below the description, the event schedule is listed: 'Starts Nov 24, 2021, 2:00 PM' and 'Ends Nov 26, 2021, 5:00 PM' in the 'Europe/Rome' timezone. At the bottom, there is a registration section with a blue 'Registration' button and the text 'Registration for this event is currently open.' To the right of this text is a user profile icon with the number '123' and a blue 'Register now >' button.

## Summary

- ▶ Strong2020 PrecisionSM Web site at <https://precision-sm.github.io/>
- ▶ started campaign of submission of published  $\sigma(e^+e^- \rightarrow \text{hadrons})$  measurements to HEPData
- ▶ annotated database of  $\sigma(e^+e^- \rightarrow \text{hadrons})$  measurements being assembled
- ▶ interactive visualization of data in responsive plots
- ▶ initial documentation with example code
- ▶ ultimate goal: open source calculation of  $a_\mu^{\text{HVP,LO}}$