Preliminary combination of the KLOE08, KLOE10 and KLOE12 ISR measurements

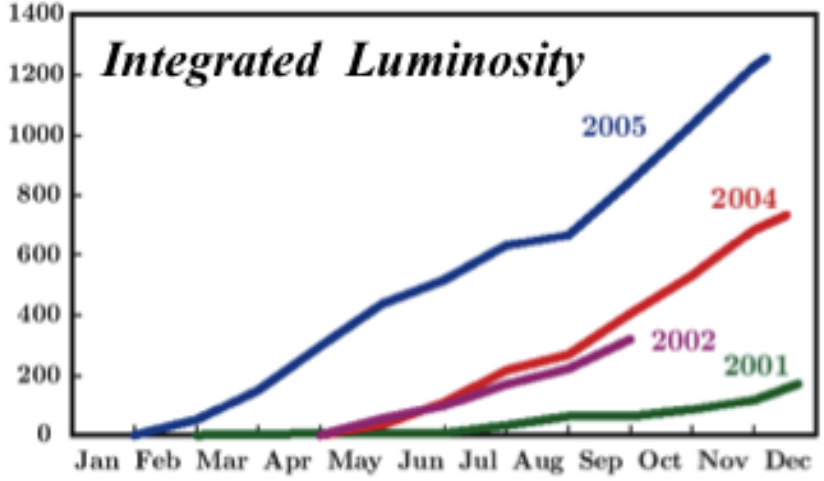
A. Keshavarzi, S. E. Müller, T. Teubner, G. Venanzoni

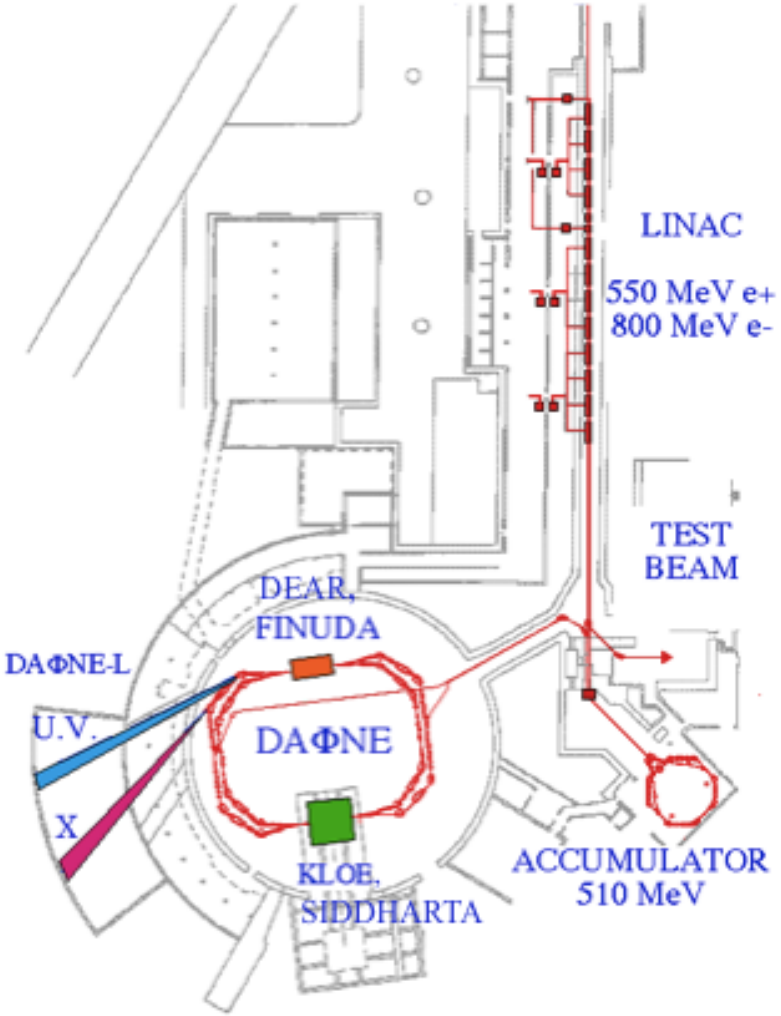
on behalf of the KLOE-2 collaboration

First Workshop of the Muon g-2 Theory Initiative
Q-Center St. Charles, 3-6 June 2017

DAΦNE: A ϕ factory

e^+e^- collider with $\sqrt{s} = m_\phi \simeq 1.02$ GeV





Peak luminosity $L_{\text{peak}} = 1.4 \cdot 10^{32} \text{cm}^{-2}\ \text{s}^{-1}$

Total KLOE int. luminosity:

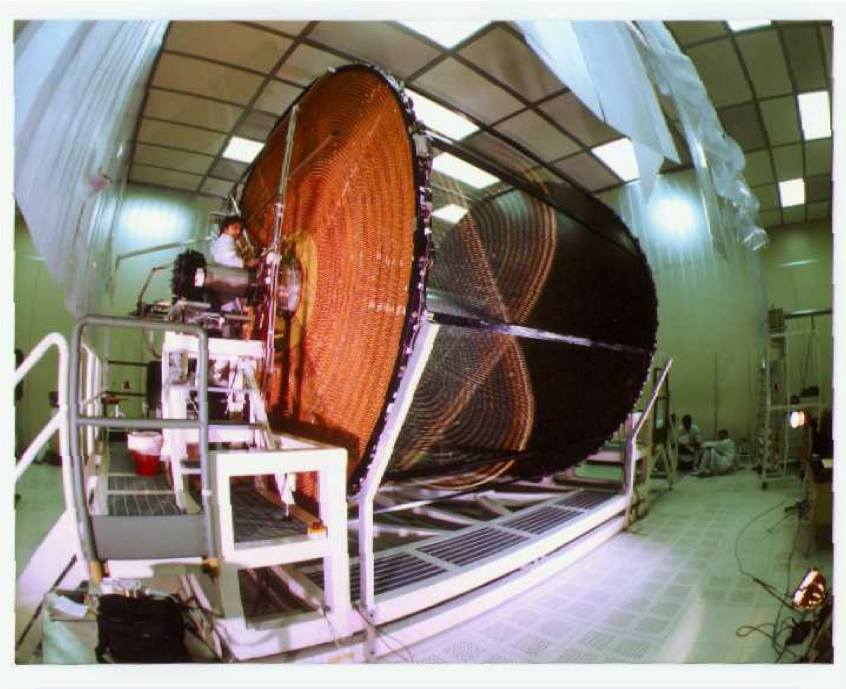
$$\int L \mathrm{d}t \sim 2.1\ \text{fb}^{-1}\ (2001 - 05)$$

2006:

- Energy scan with 4 points around m_ϕ
- 250 pb^{-1} at $\sqrt{s} = 1$ GeV

KLOE:

Driftchamber:

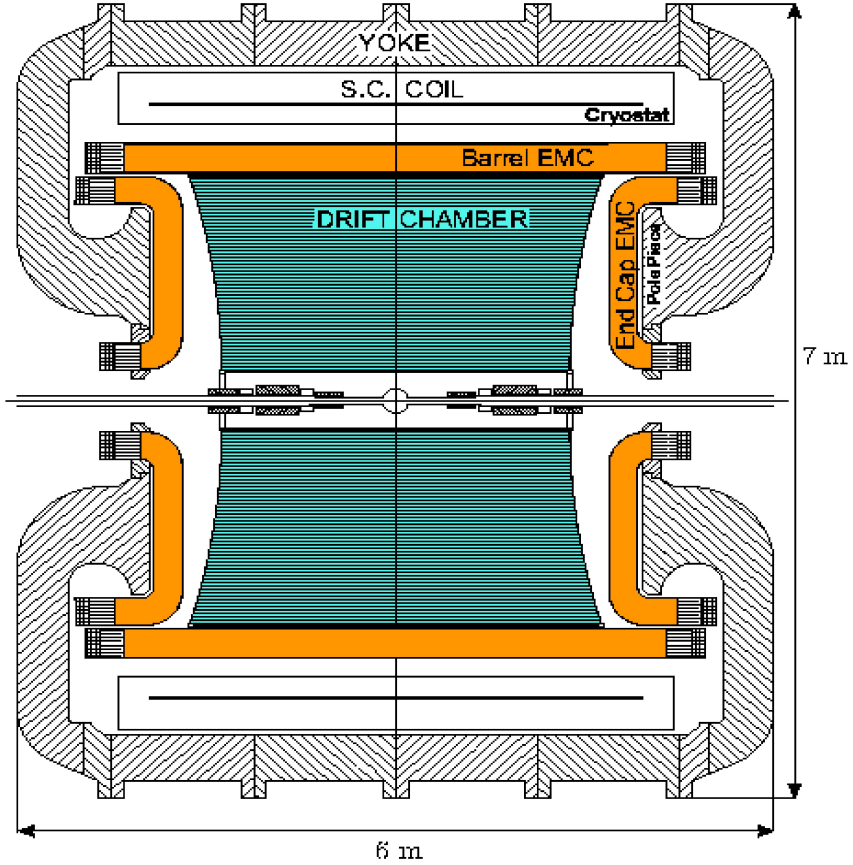


$\sigma_{r\phi} = 150\mu m$, $\sigma_z = 2mm$

$\sigma_p/p = 0.4\%$

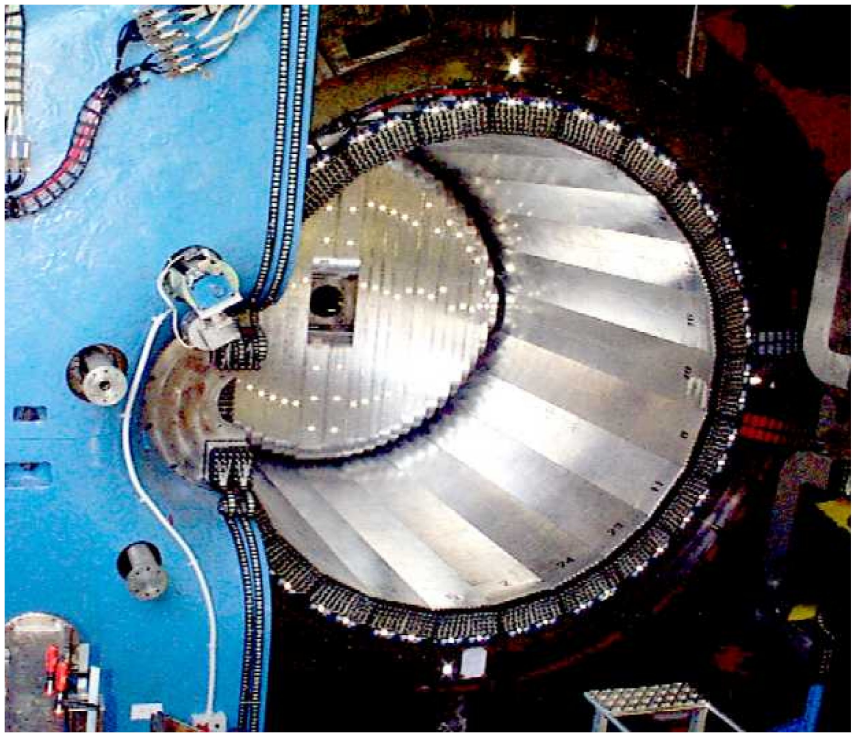
Excellent momentum resolution

KLOE Detector



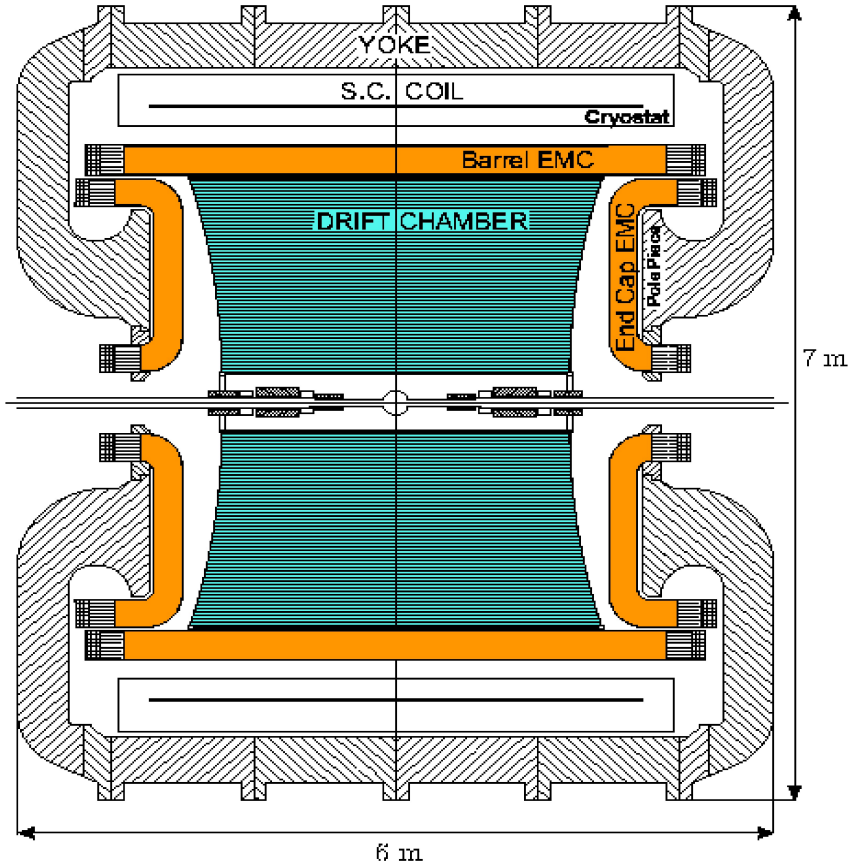
KLOE:

Electromagnetic Calorimeter



$$\sigma_t = 54\text{ps}/\sqrt{E(GeV)} \oplus 100\text{ps},$$
$$\sigma_E/E = 5.7\%/\sqrt{E(GeV)},$$
Excellent time resolution

KLOE Detector



The KLOE data sets

- KLOE05: 60 points between 0.35 and 0.95 GeV^2,
  based on 141.4 pb^{-1} of data taken in 2001[a]
  (small angle photon cuts, normalization to Bhabha and PHOKHARA radiator)
- KLOE08: 60 points between 0.35 and 0.95 GeV^2,
  based on 240.0 pb^{-1} data taken in 2002[b]
  (small angle photon cuts, normalization to Bhabha and PHOKHARA radiator)
- KLOE10: 75 points between 0.1 and 0.85 GeV^2,
  based on 232.6 pb^{-1} data taken in 2006[c] with $\sqrt{s} = 1.00$ GeV
  (large angle photon cuts, normalization to Bhabha and PHOKHARA radiator)
- KLOE12: 60 points between 0.35 and 0.95 GeV^2,
  based on 240.0 pb^{-1} data taken in 2002[d]
  (small angle photon cuts, normalization to $\mu\mu\gamma$ events)

[a] Phys. Lett. B**606** (2005) 12
[b] Phys. Lett. B**670** (2009) 285
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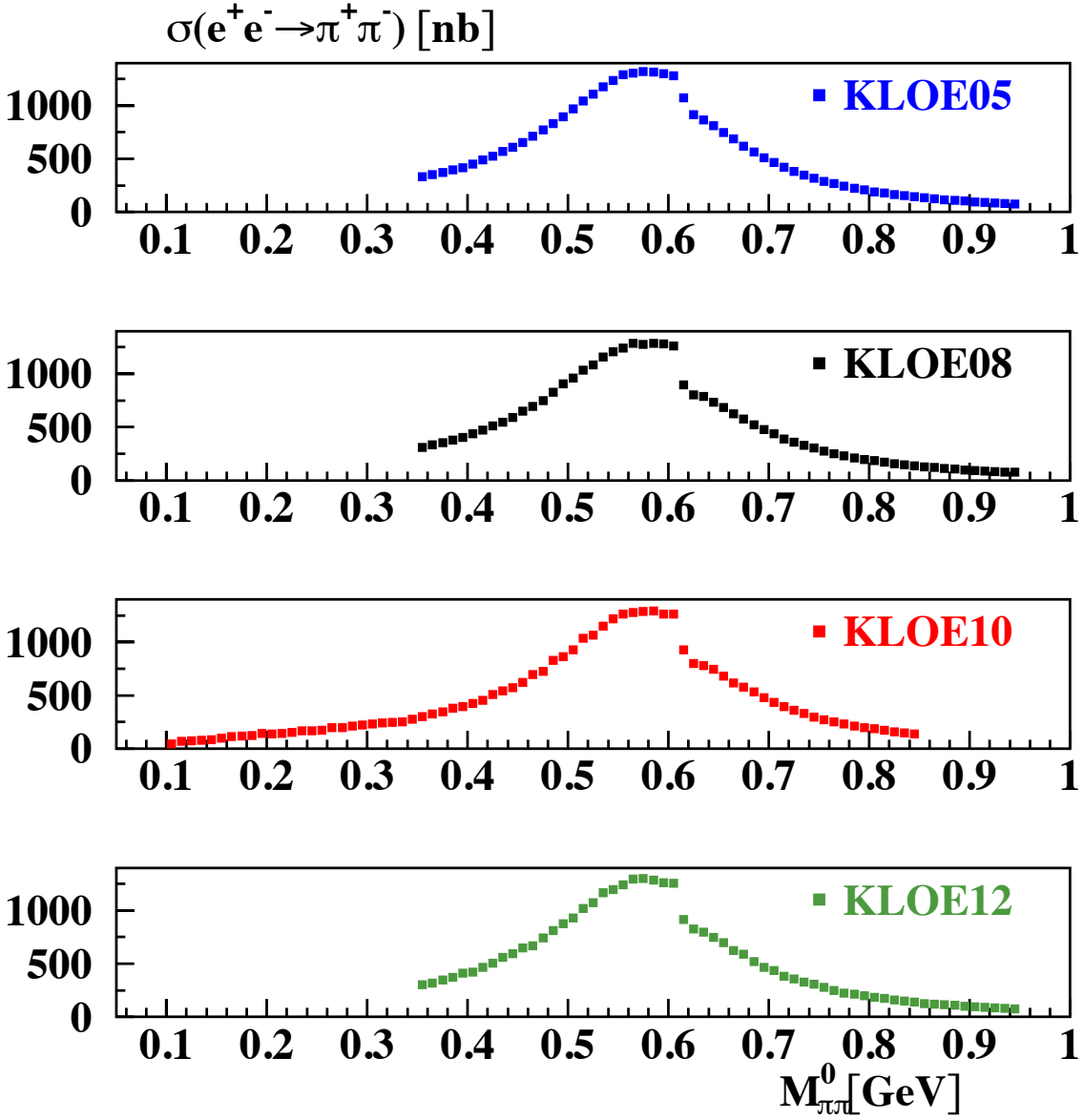

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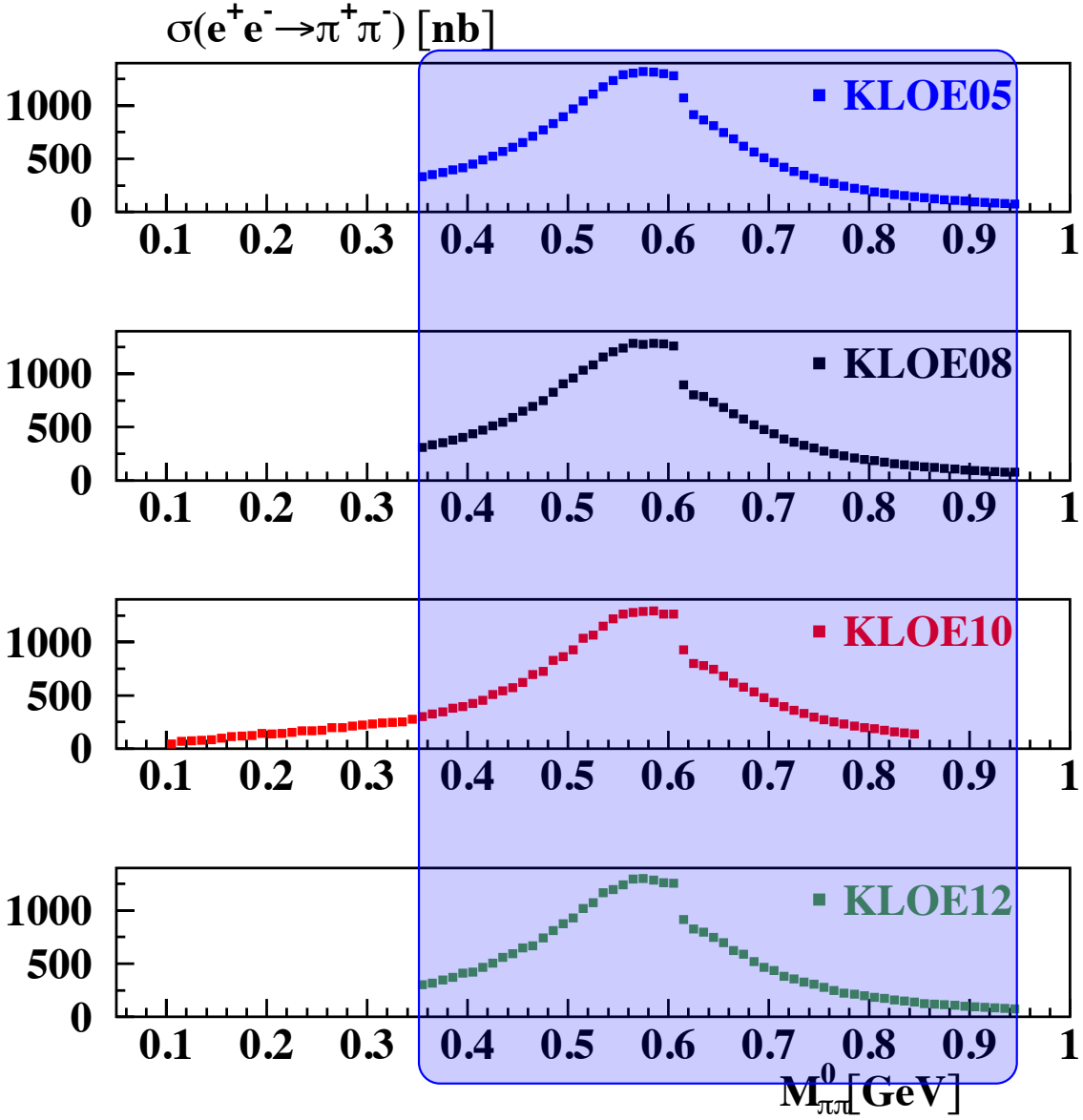

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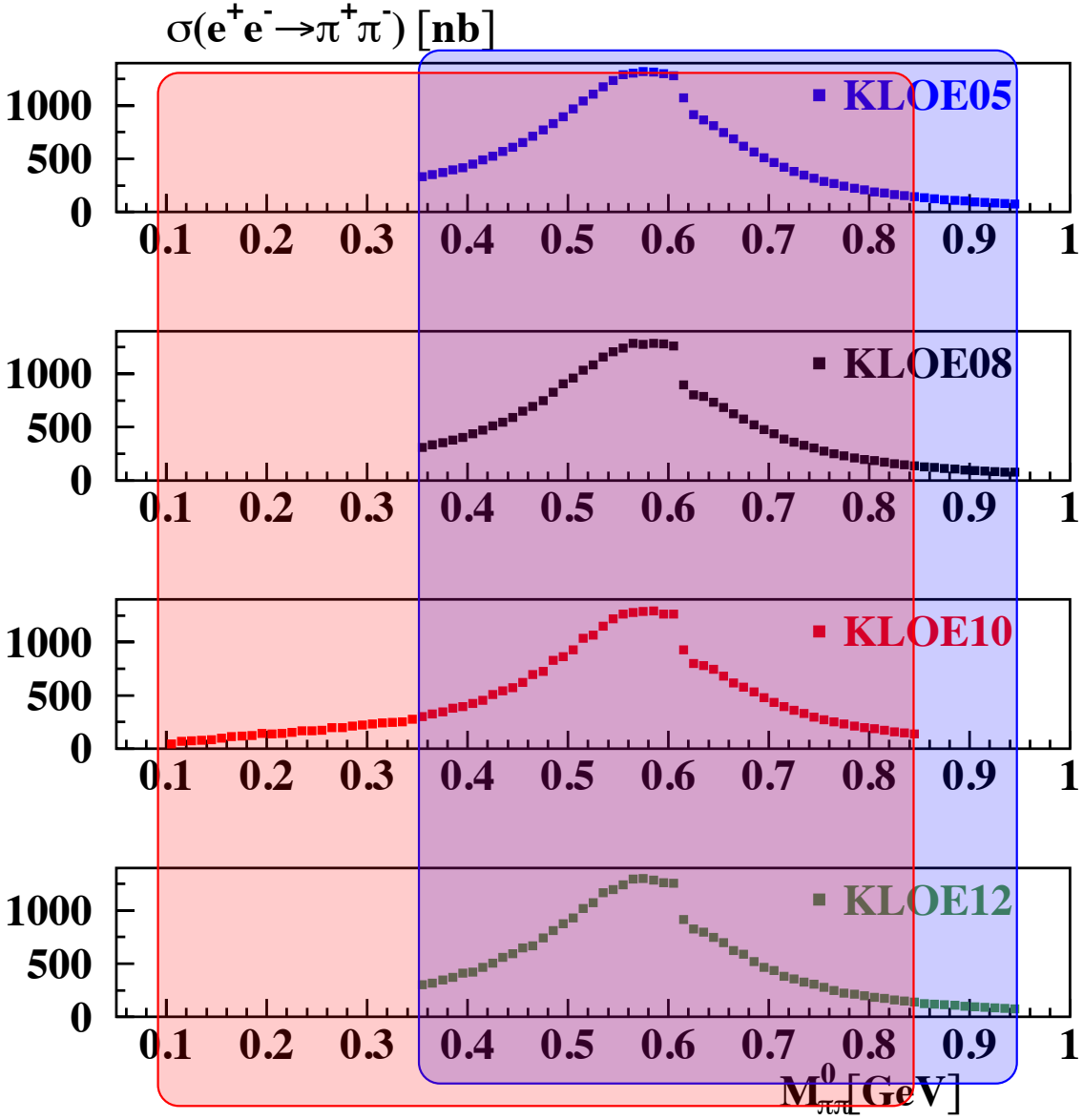

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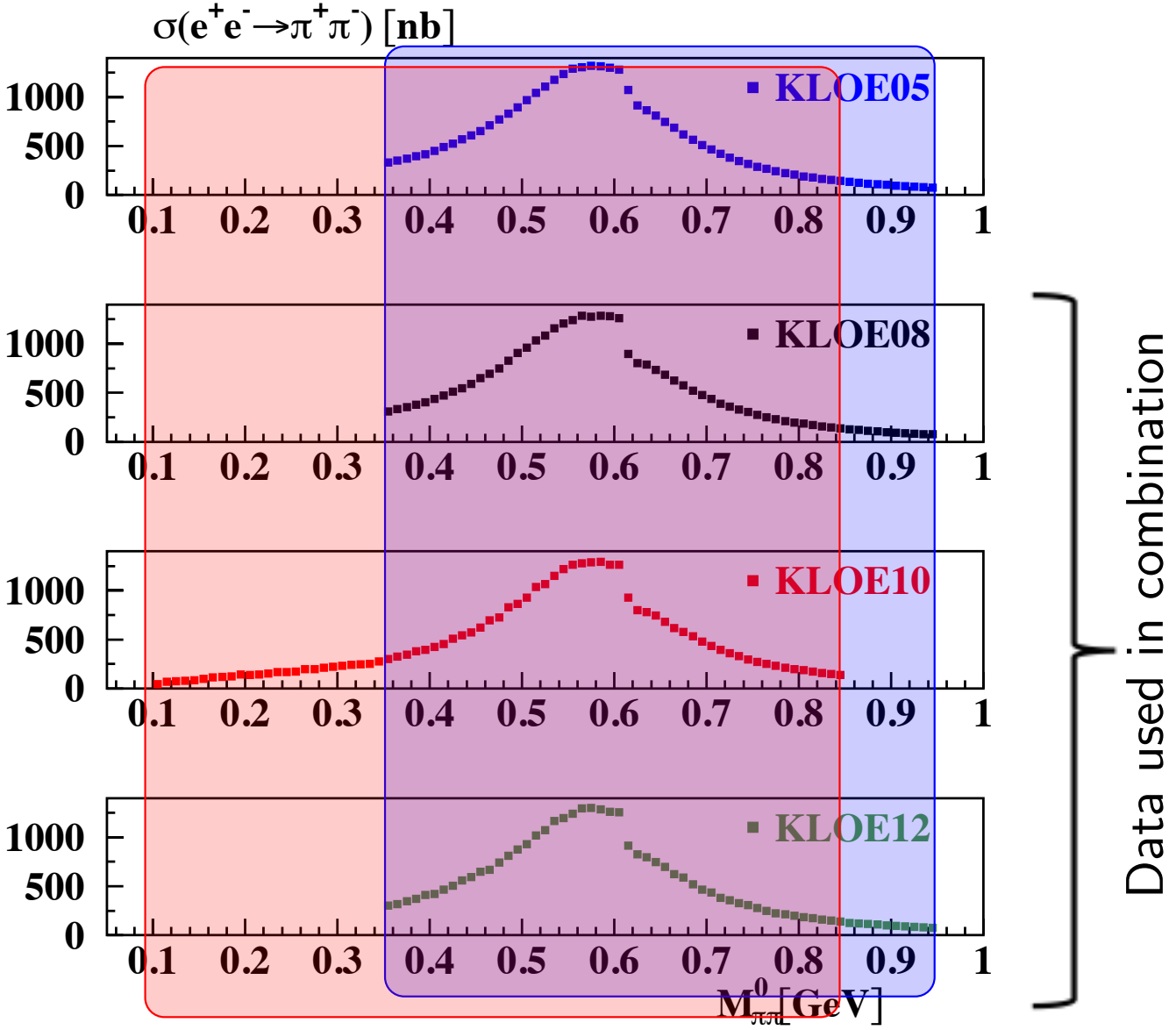

The covariance matrix

The (195×195) covariance matrix for the $60 + 75 + 60$ data points:

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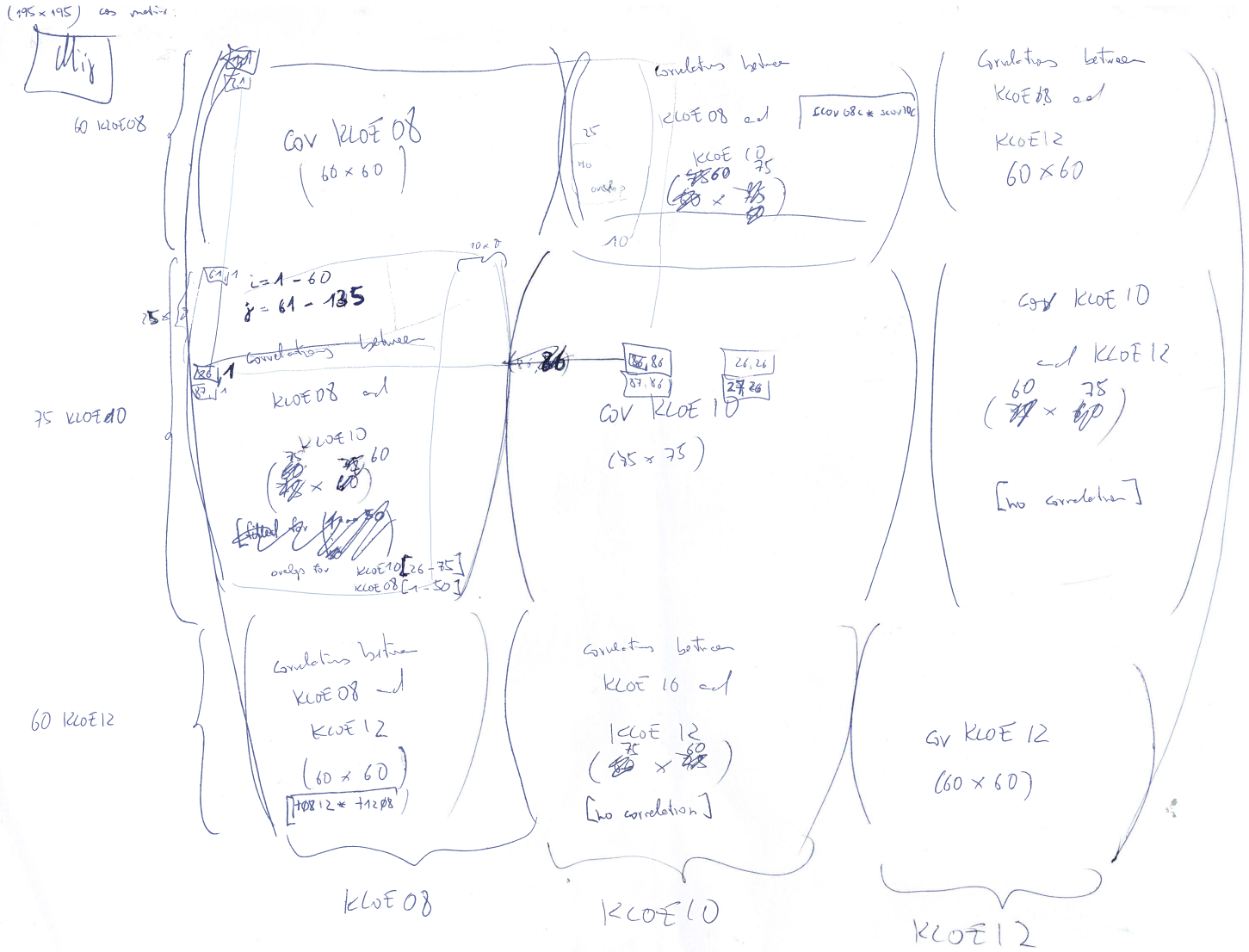

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$$
\left(\begin{array}{c|c|c}
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} \\
\begin{matrix} \text{KLOE08} \\ 60 \times 60 \end{matrix} & \begin{matrix} \cdots \\ \cdots \end{matrix} \begin{matrix} \text{KLOE0810} \\ 60 \times 75 \end{matrix} \begin{matrix} \cdots \\ \cdots \end{matrix} & \begin{matrix} \text{KLOE0812} \\ 60 \times 60 \end{matrix} \\
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} \\
\hline
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} \\
\begin{matrix} \text{KLOE1008} \\ 75 \times 60 \end{matrix} & \begin{matrix} \cdots \\ \cdots \end{matrix} \begin{matrix} \text{KLOE10} \\ 75 \times 75 \end{matrix} \begin{matrix} \cdots \\ \cdots \end{matrix} & \begin{matrix} \text{KLOE1012} \\ 75 \times 60 \end{matrix} \\
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} \\
\hline
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} & \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix} \\
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&
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \text{KLOE0810} & \cdots \\ \cdots & 60 \times 75 & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix}
&
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \text{KLOE0812} & & \\ 60 \times 60 & & \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix}
\\ \hline
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \text{KLOE1008} & & \\ 75 \times 60 & & \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix}
&
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&
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\\ \hline
\begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ \text{KLOE1208} & & \\ 60 \times 60 & & \\ \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{matrix}
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&
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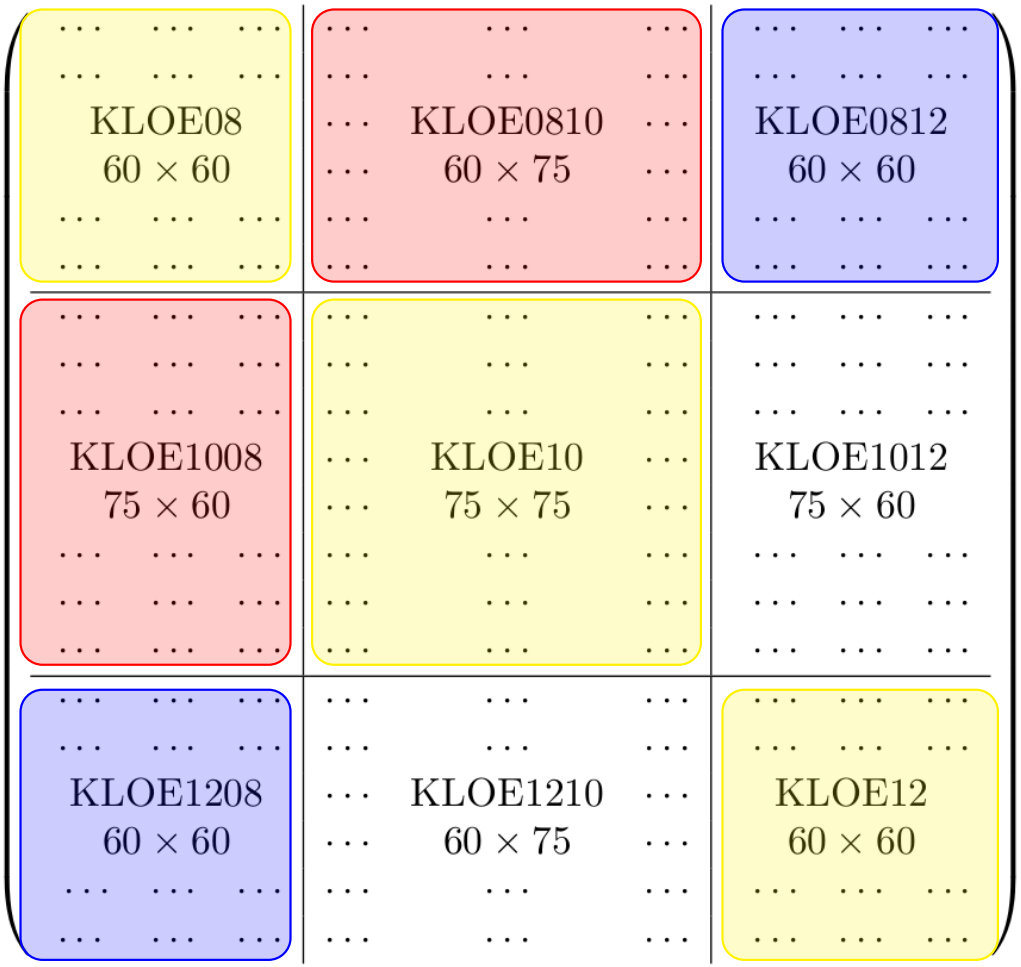

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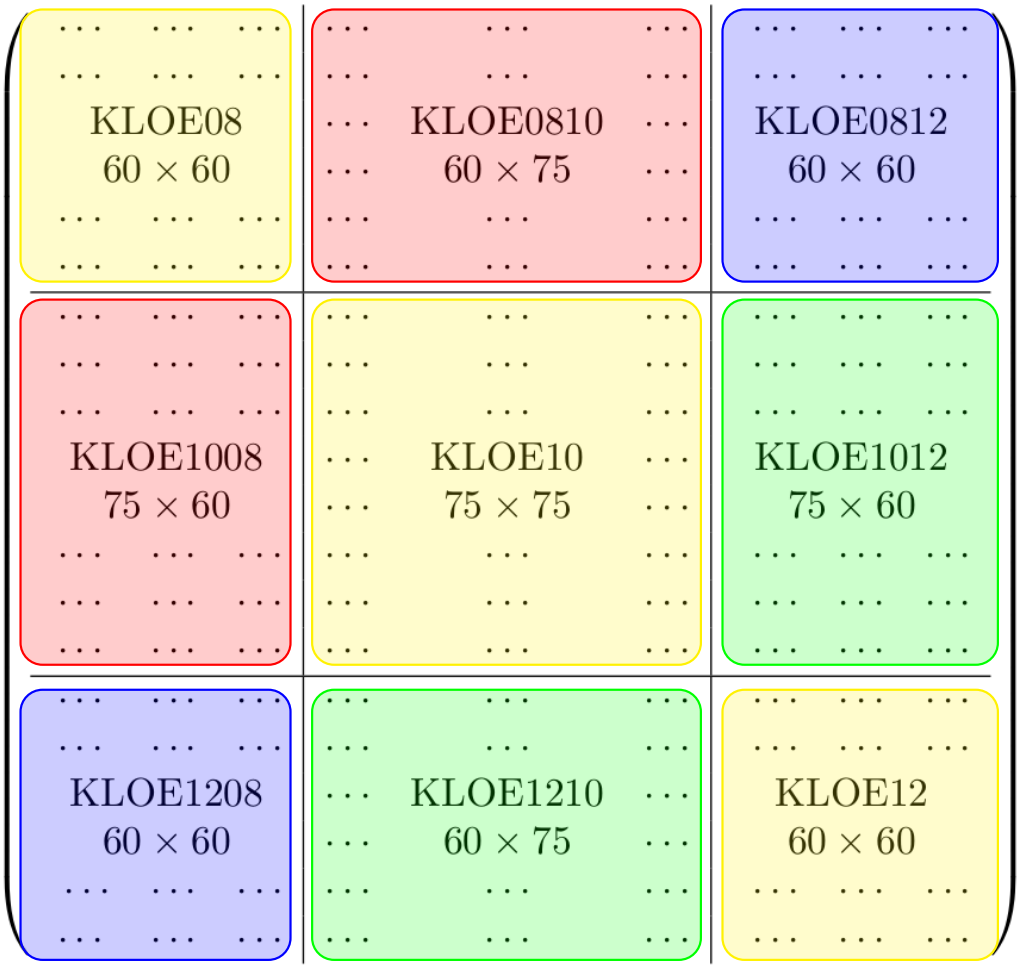
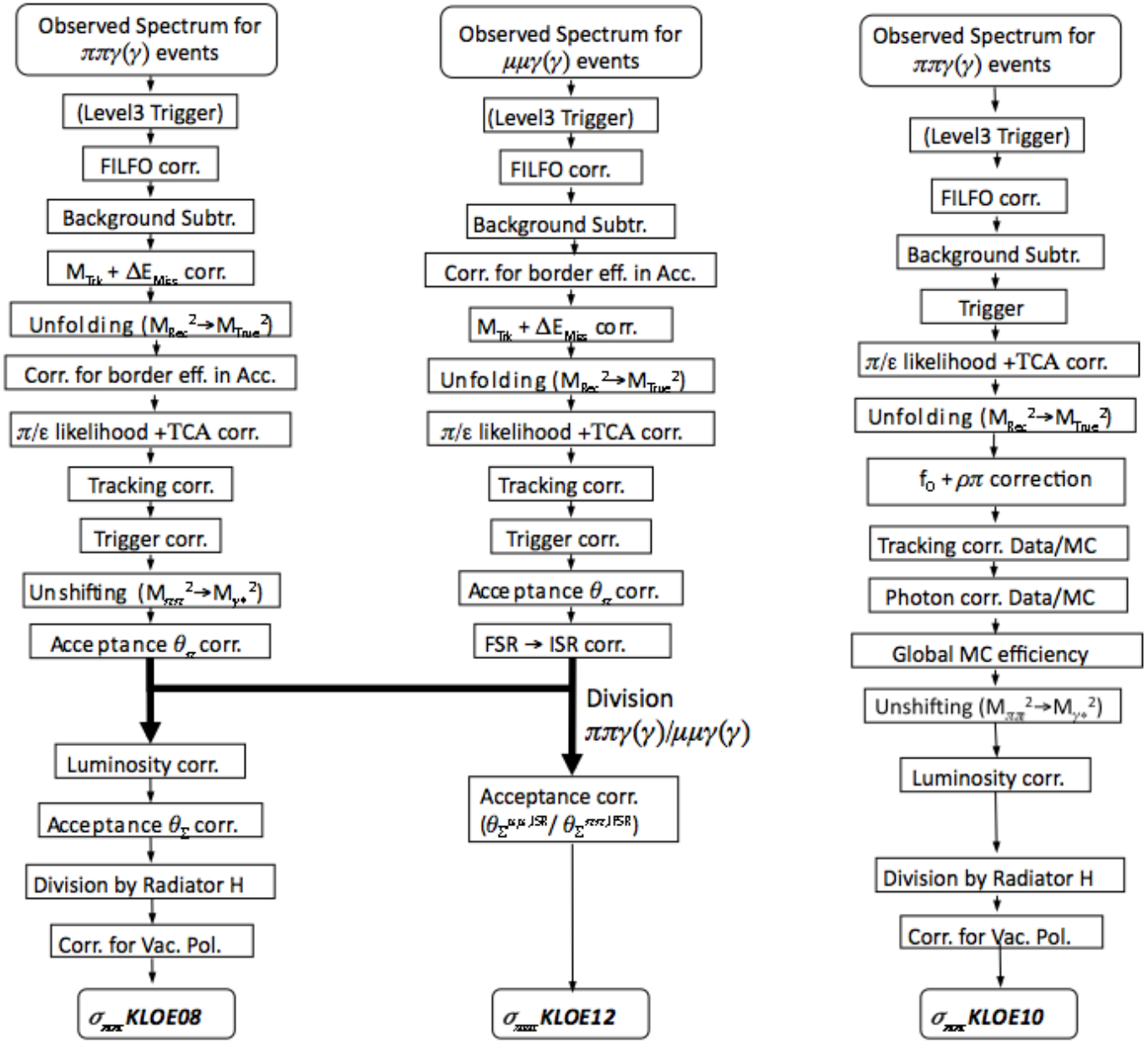


The analysis flow



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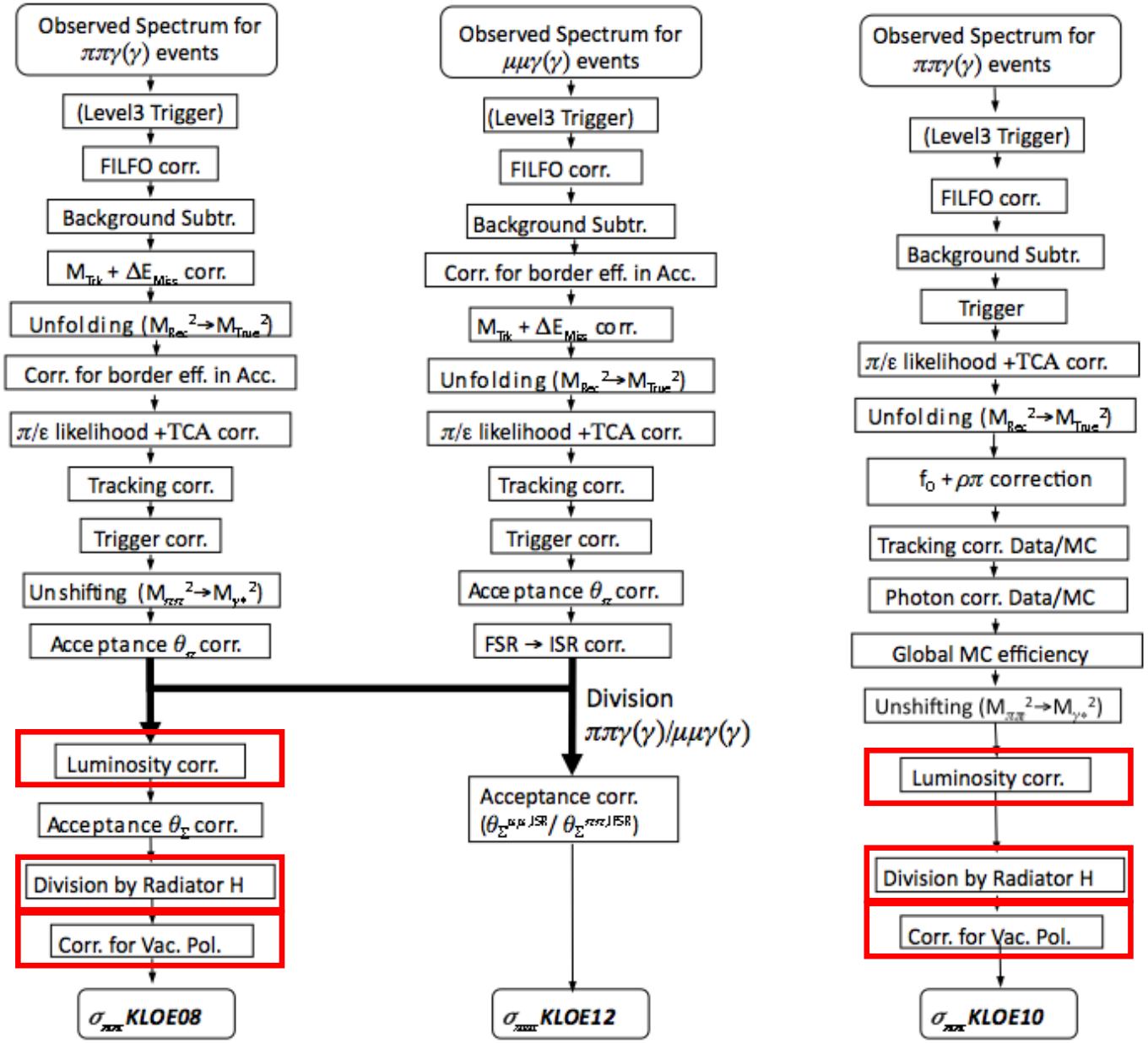

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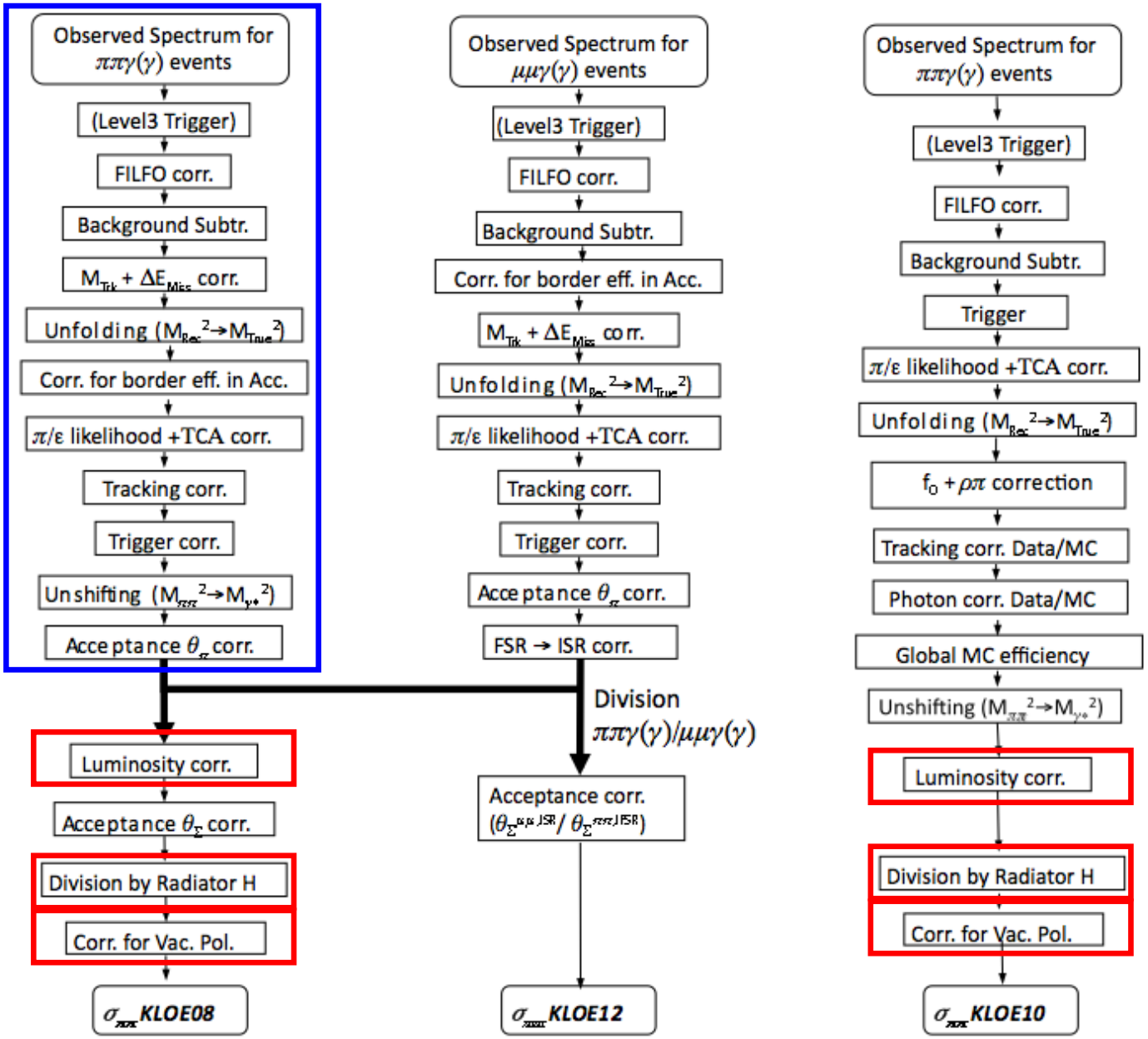

The elements of the covariance matrices

- Diagonal matrix blocks are composed from the statistical covariance matrices of the individual measurements and the fully bin-per-bin-correlated systematic contributions
- Syst. correlations between KLOE08 and KLOE10 analyses because both analyses share identical radiative corrections (Luminosity, radiator function and vacuum polarization correction)
- Stat. and syst. correlations between KLOE08 and KLOE12 analyses due to KLOE08 $\pi\pi\gamma$-events enter KLOE12 analysis
- No stat. or syst. correlations are present between KLOE10 and KLOE12 analyses

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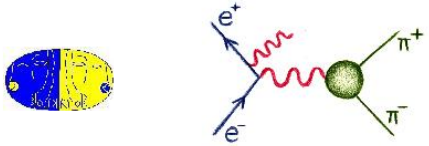
The PPG2014 covariance matrices



KLOE ppg 2014 web page

Combination of KLOE12, KLOE10, KLOE08 measurements, see for details S. Mueller, contribution to Mini-Proceedings, 15th meeting of the Working Group on Rad. Corrections and MC Generators for Low Energies, http://arxiv.org/abs/1406.4639

- *Data files of the bare cross section $\sigma(e^+e^- \to \pi^+\pi^-)$ (which includes FSR and excludes VP) are organized in a 195 dim Vector as follows:*
- *KLOE08 (1:60)*
- *KLOE10 (61:135)*
- *KLOE12 (136:195)*

Please note that KLOE08 and KLOE10 has been obtained correcting the Vacuum Polarization with Fred Jegerlehner 2003 routine (VP03). If you want to apply your Vacuum Polarization correction (For example Fred's new one VP12) you should multiply vector components (1:135) for VP12/VP03.

- *Statistical errors (195x195 matrix):*

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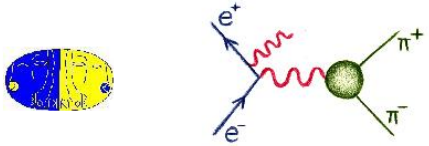
27 Feb 2015 G.V.

The PPG2014 covariance matrices



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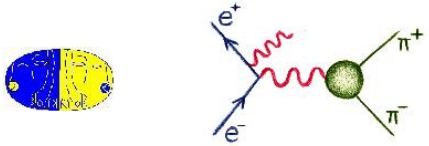
27 Feb 2015 G.V.

F. Ignatov (25.5.2016):

- Syst. covariance matrix has negative eigenvalues

The PPG2014 covariance matrices



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27 Feb 2015 G.V.

F. Ignatov (25.5.2016):

- Syst. covariance matrix has negative eigenvalues

Don't use!

The PPG2017 covariance matrices (Preliminary!)

During the (re-) evaluation of the covariance matrices, the following updates have been applied to the KLOE data sets:

- The analyses have been updated with respect to the precision of input parameters and fundamental constants
- The data are not rounded to prevent precision loss due to rounding cut-off
- KLOE08 and KLOE10 data have been corrected for vacuum polarization using an updated routine (real and imaginary part)
  - this results in a reduction of the corresponding $a_\mu^{\pi\pi}$-value by $0.6 - 0.7 \times 10^{-10}$
- An improved error analysis for the KLOE12 data resulted in a slight decrease of the systematic uncertainty

The PPG2017 covariance matrices (Preliminary!)

After the updates on the cross section data, the following values for $a_\mu^{\pi\pi}$ are obtained:

KLOE08: $\Delta a_\mu^{\pi\pi}[0.35 - 0.95\,\mathrm{GeV}^2] = (386.6 \pm 3.3) \times 10^{-10}$

was: $\Delta a_\mu^{\pi\pi}[0.35 - 0.95\,\mathrm{GeV}^2] = (387.2 \pm 3.4) \times 10^{-10}$

KLOE10: $\Delta a_\mu^{\pi\pi}[0.10 - 0.85\,\mathrm{GeV}^2] = (477.8 \pm 7.0) \times 10^{-10}$

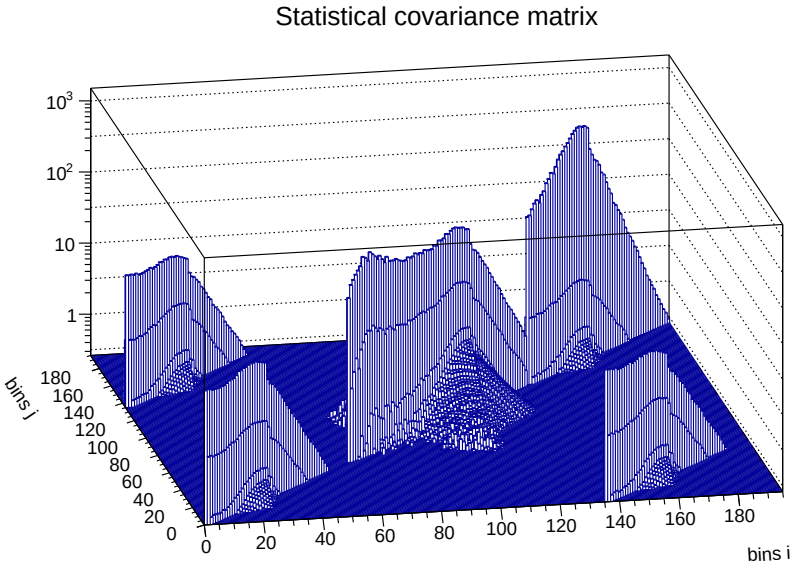
was: $\Delta a_\mu^{\pi\pi}[0.10 - 0.85\,\mathrm{GeV}^2] = (478.5 \pm 7.0) \times 10^{-10}$

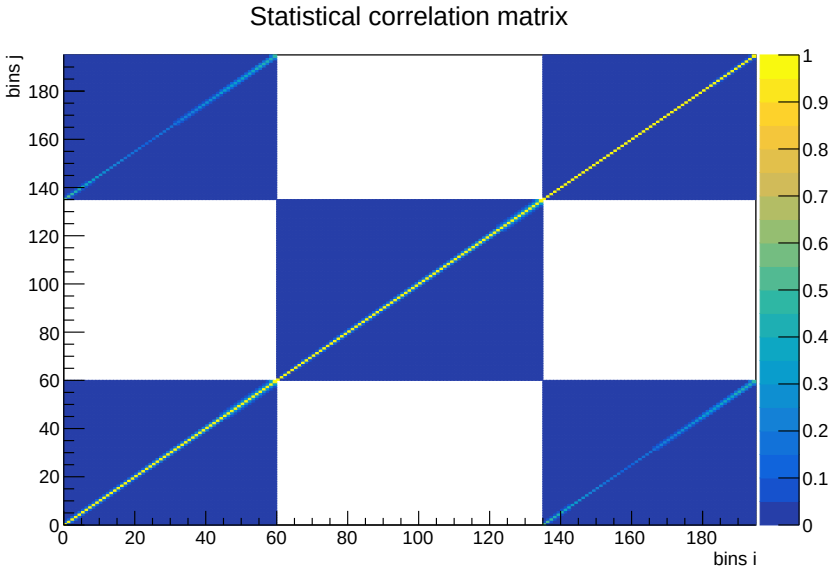
KLOE12: $\Delta a_\mu^{\pi\pi}[0.35 - 0.95\,\mathrm{GeV}^2] = (385.1 \pm 2.6) \times 10^{-10}$

was: $\Delta a_\mu^{\pi\pi}[0.35 - 0.95\,\mathrm{GeV}^2] = (385.1 \pm 2.9) \times 10^{-10}$

The PPG2017 covariance matrices (Preliminary!)

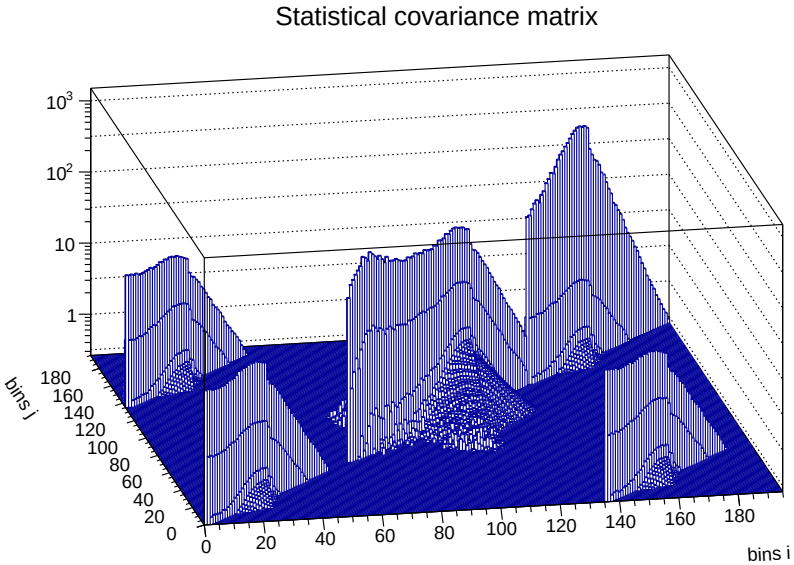
Statistical covariance and correlation matrix:

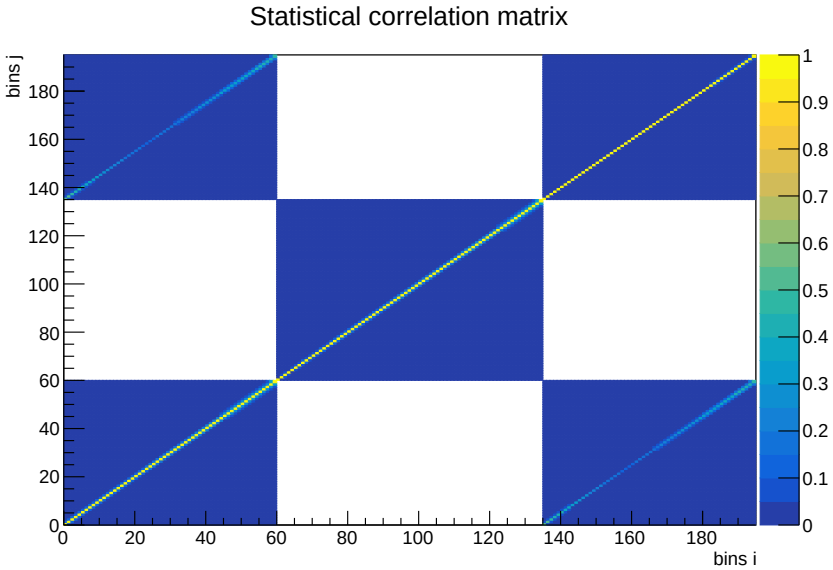




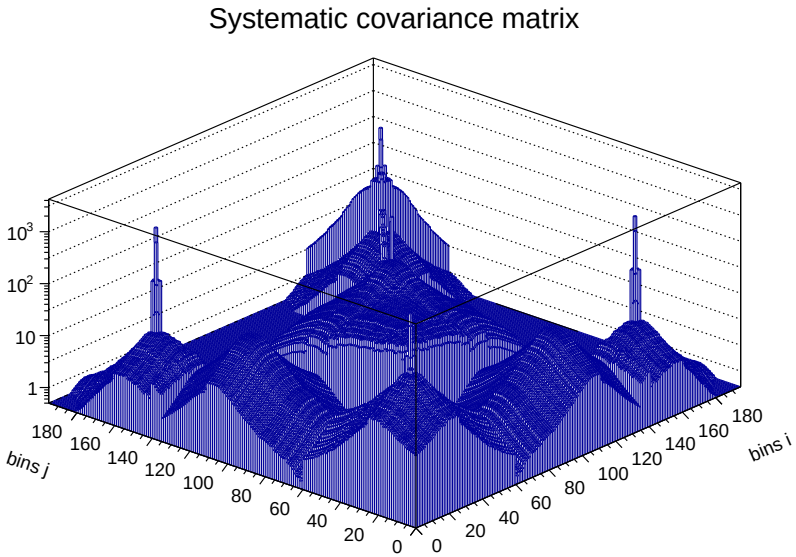
The PPG2017 covariance matrices (Preliminary!)

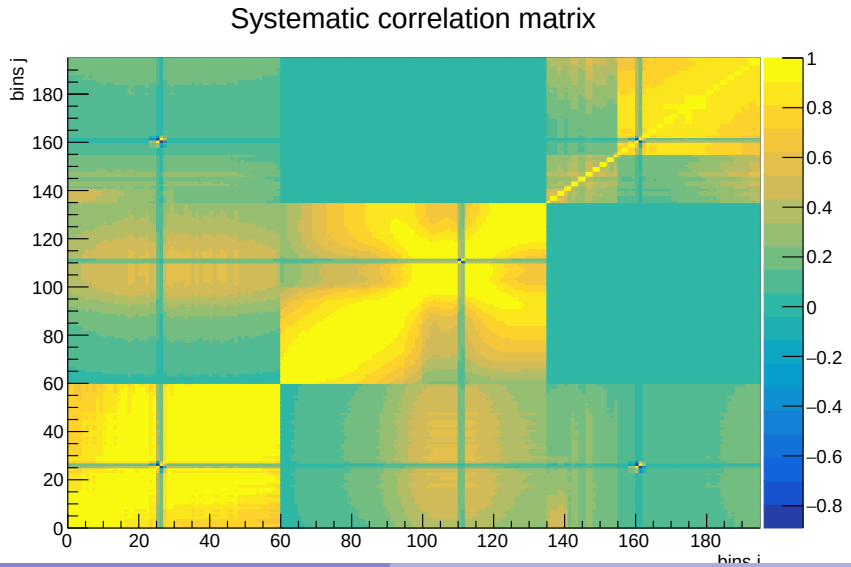
Statistical covariance and correlation matrix:





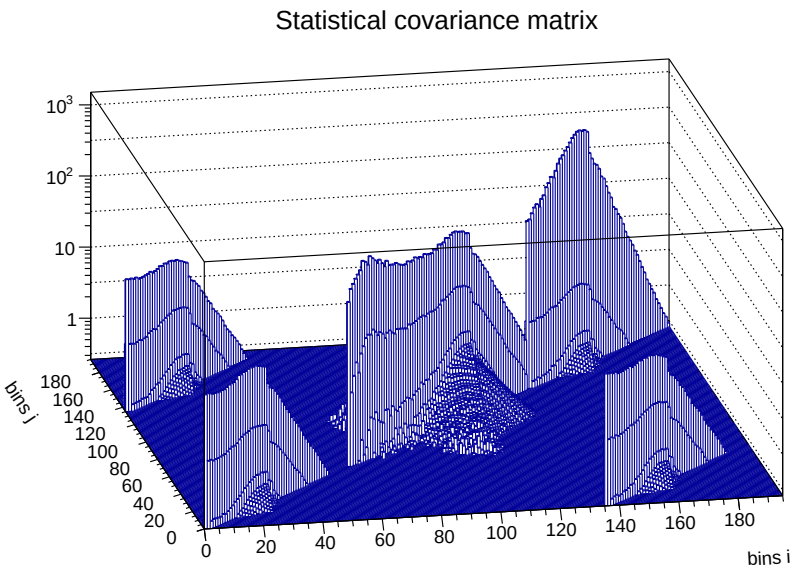
Systematic covariance and correlation matrix:

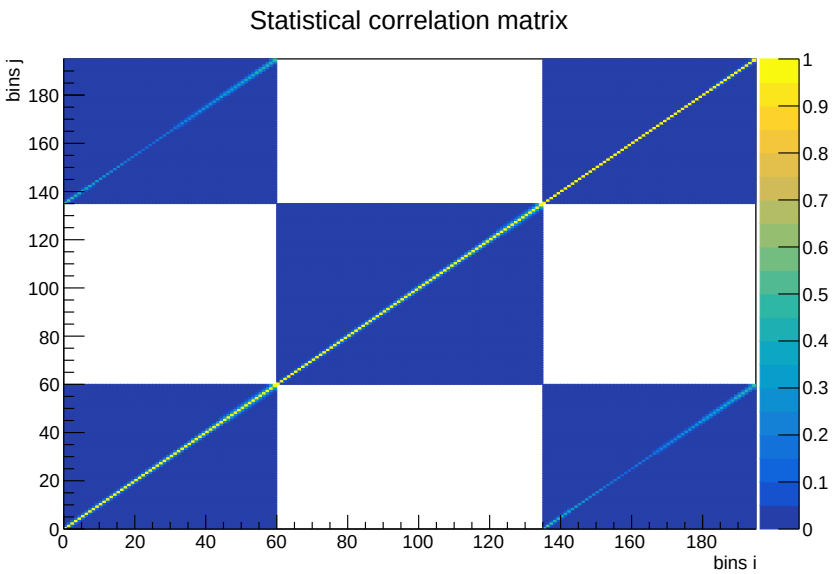




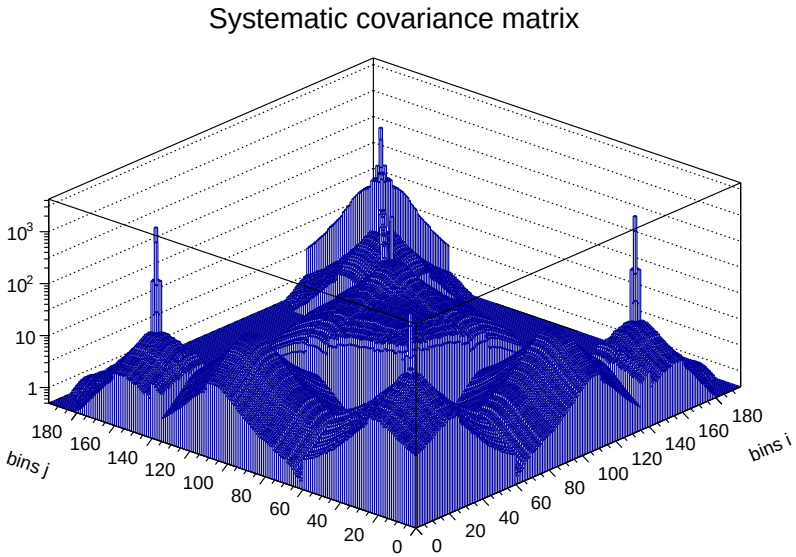
The PPG2017 covariance matrices (Preliminary!)

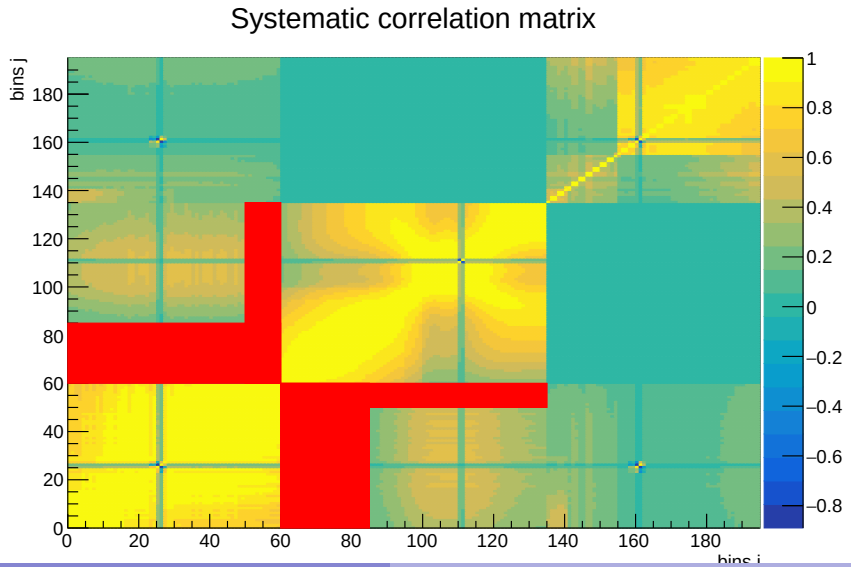
Statistical covariance and correlation matrix:





Systematic covariance and correlation matrix:

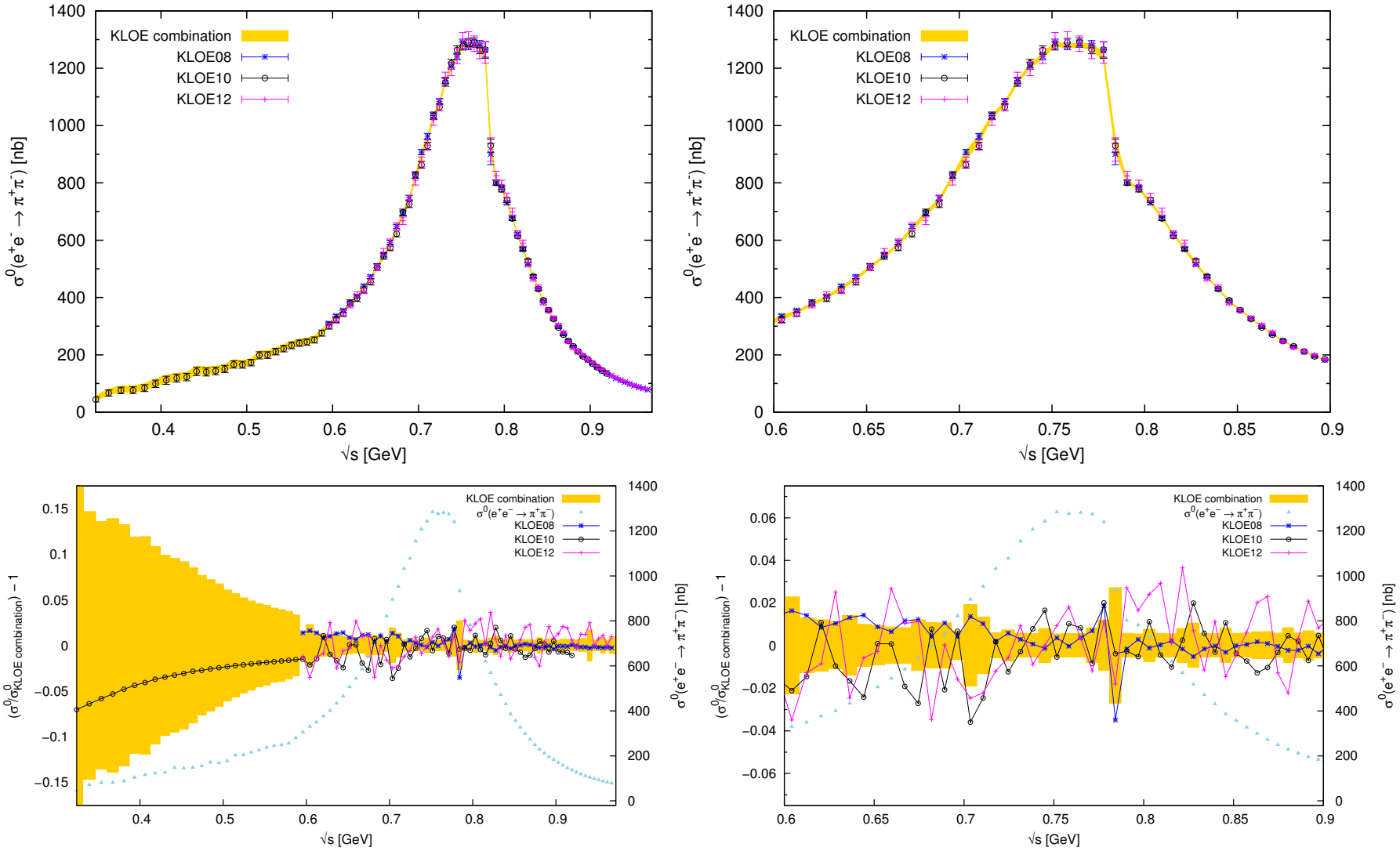




Set to "0" in PPG2014!

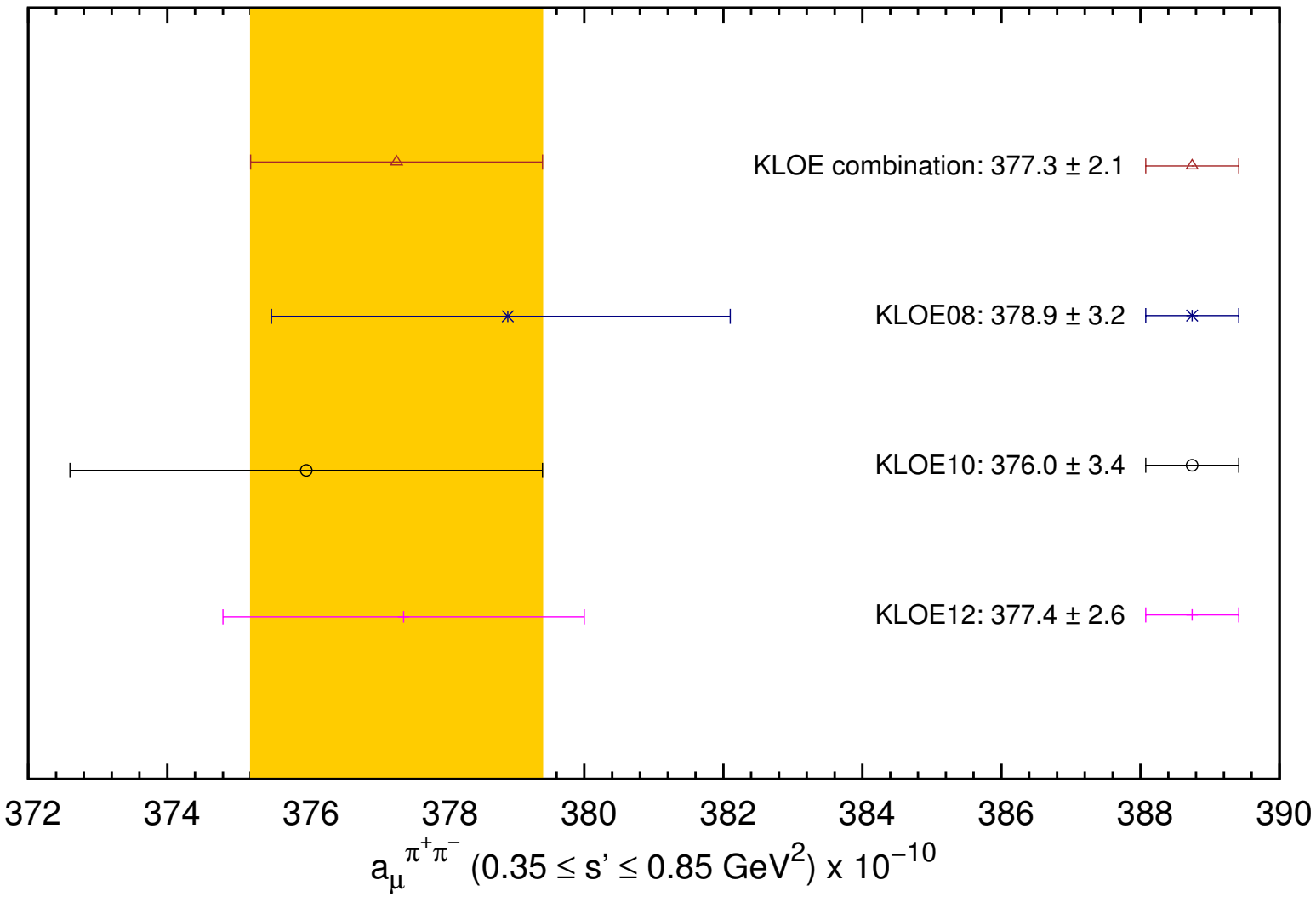
Preliminary combination of KLOE data sets

Using the obtained covariance matrices, the KLOE data are combined using an bias-free iterative linear χ^2 minimisation (Talk by A. Keshavarzi)



Preliminary combination of KLOE data sets

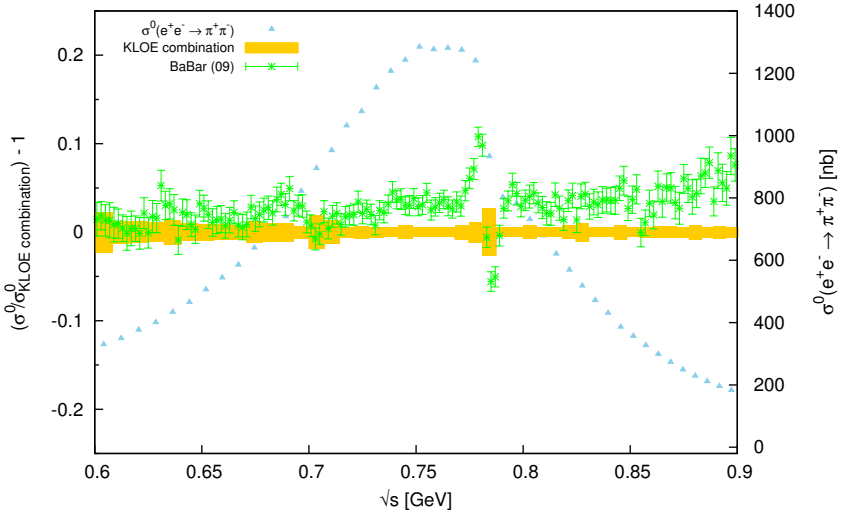
Estimates of $\Delta a_\mu^{\pi\pi}$ in the range $0.35 \leq s' \leq 0.85$ GeV^2 for the different KLOE analyses and the prel. combination:



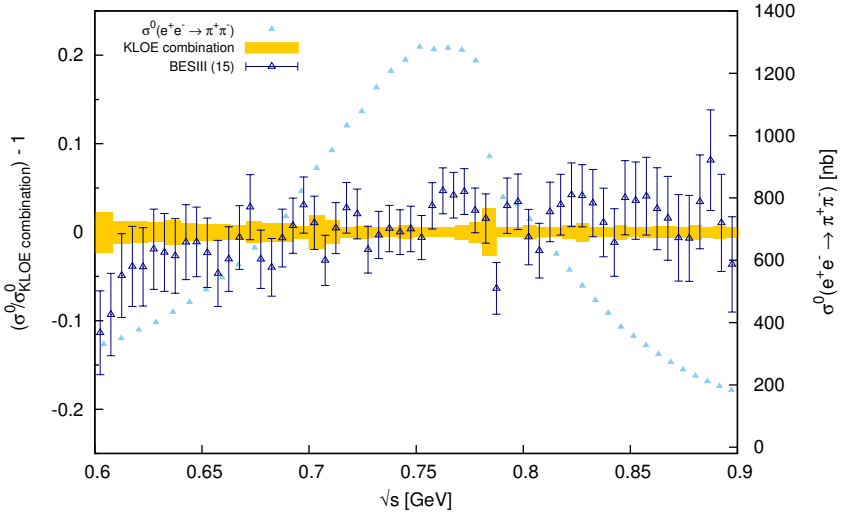
Preliminary combination of KLOE data sets

Comparison with data from other experiments:

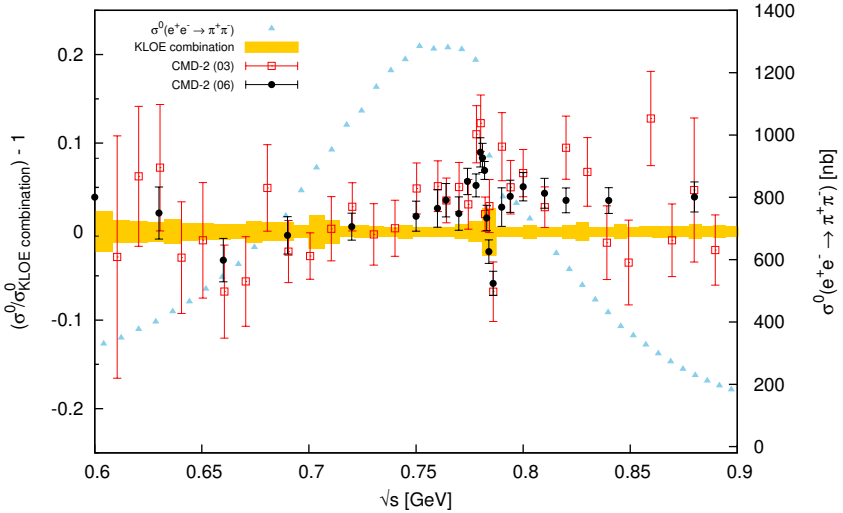
Comp. with BaBar



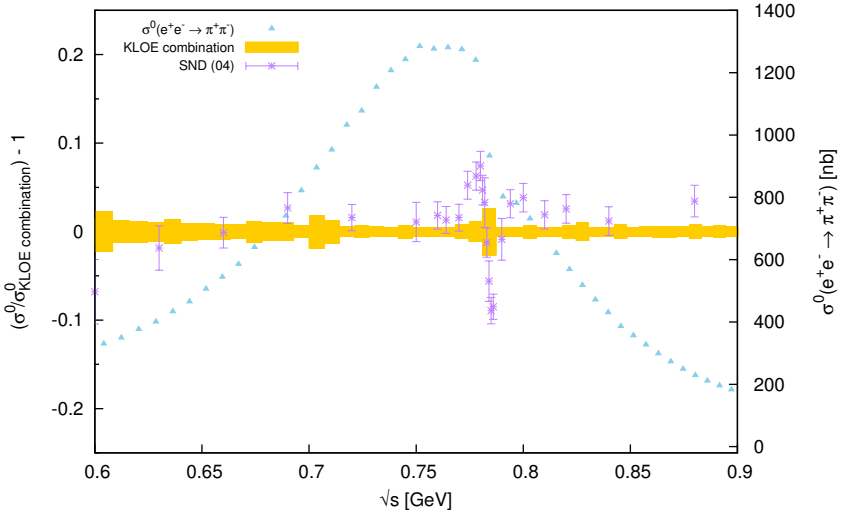
Comp. with BESIII



Comp. with CMD

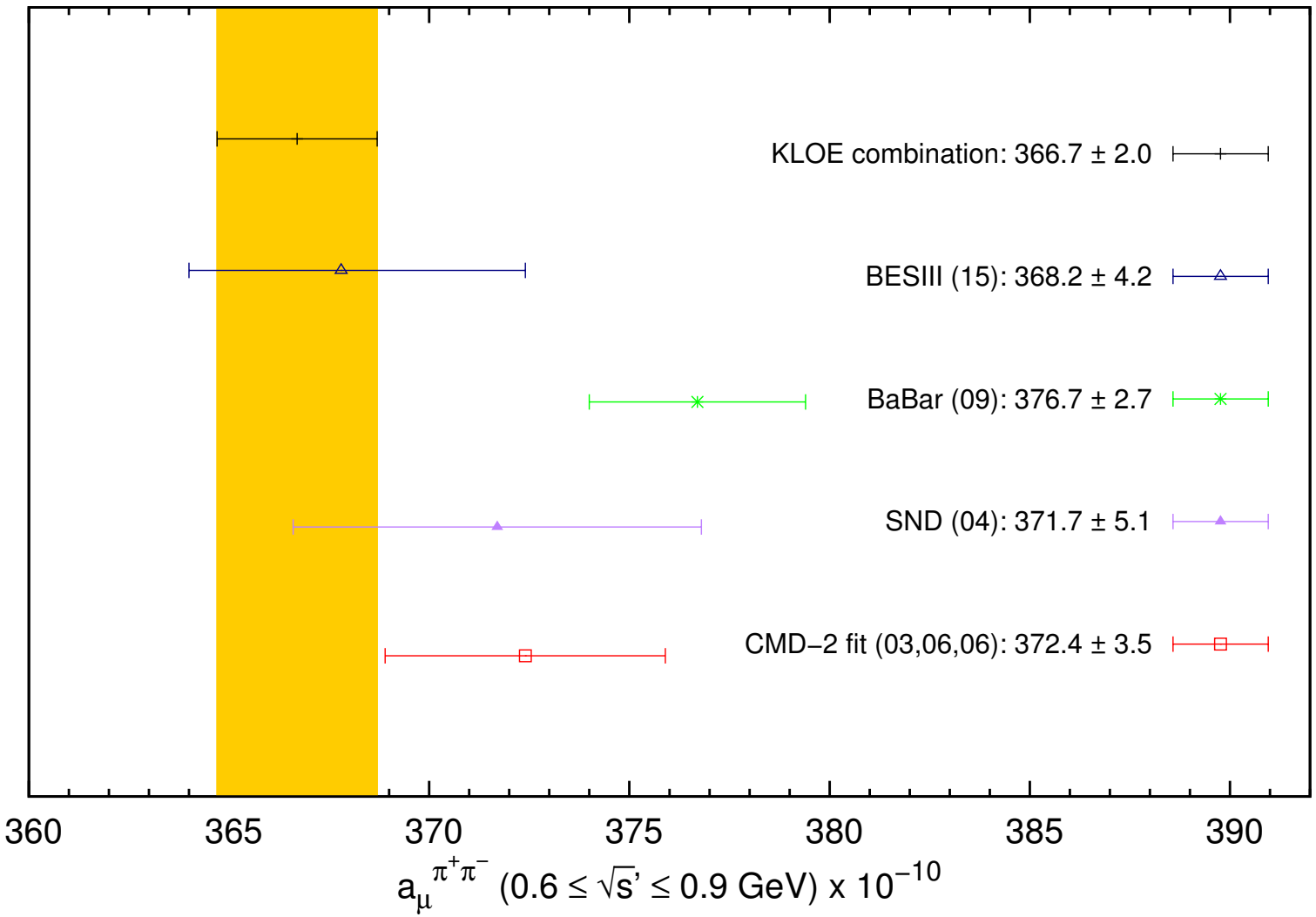


Comp. with SND



Preliminary combination of KLOE data sets

Estimates of $\Delta a_\mu^{\pi\pi}$ in the range $0.6 \leq \sqrt{s'} \leq 0.9$ GeV for different experiments:



Summary and Conclusion

- We have re-evaluated the 195×195 statistic and systematic covariance matrices for the three KLOE ISR analyses KLOE08, KLOE10 and KLOE12
- Using these covariance matrices, a preliminary combined estimate in the range between 0.1 and 0.95 GeV^2 has been constructed
- Results are currently evaluated by the KLOE-2 collaboration, after final blessing will be put on the KLOE ppg-webpage: `http://www.lnf.infn.it/kloe/ppg/`
- This work has been started and greatly profited from discussions within the framework of the Radio MonteCarLOW group `https://www.lnf.infn.it/wg/sighad/`

SPARE SLIDES

Zoom around the $\rho - \omega$ region: