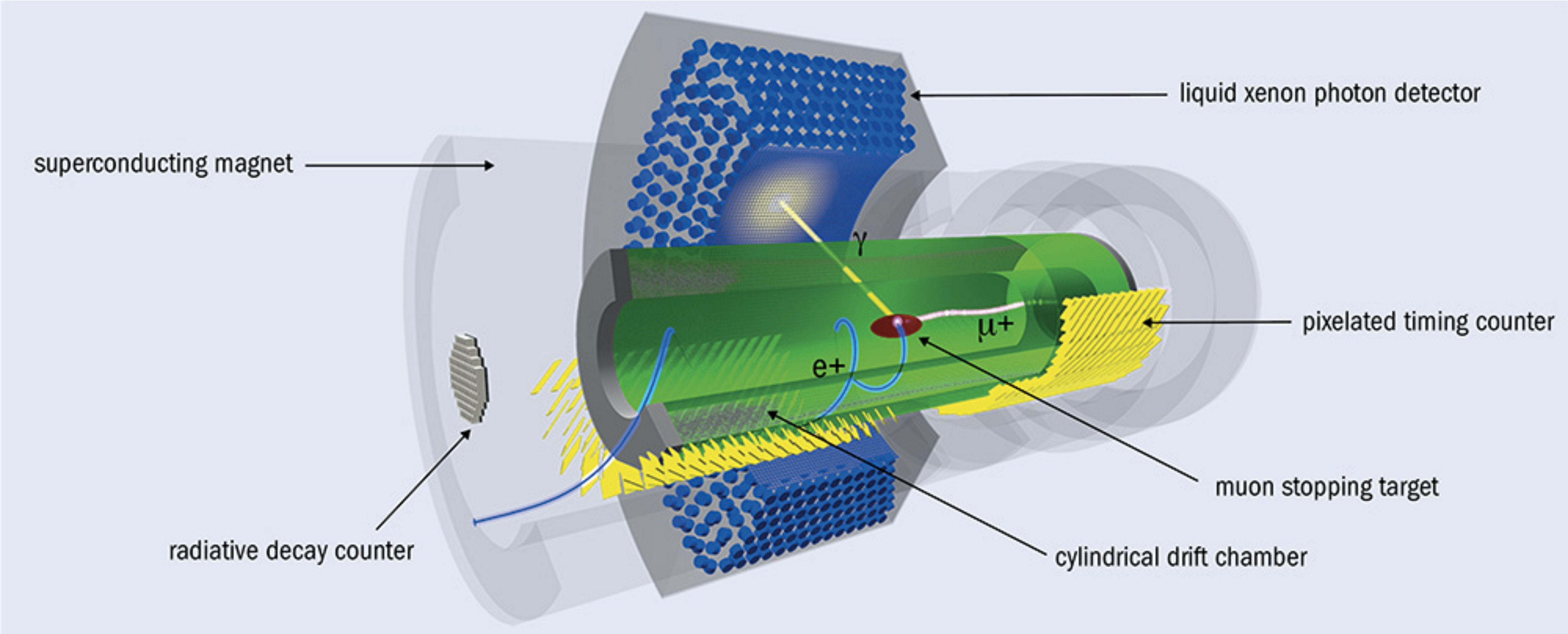


Lepton Flavor Violation Searches with the MEG-II Experiment

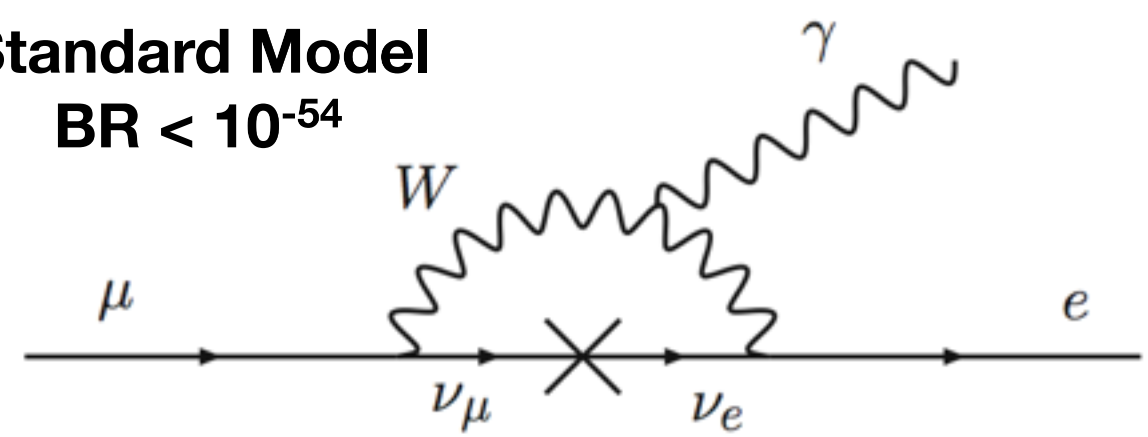
Francesco Renga
INFN Roma
for the MEG II Collaboration

Lepton Flavor Conservation in the Standard Model

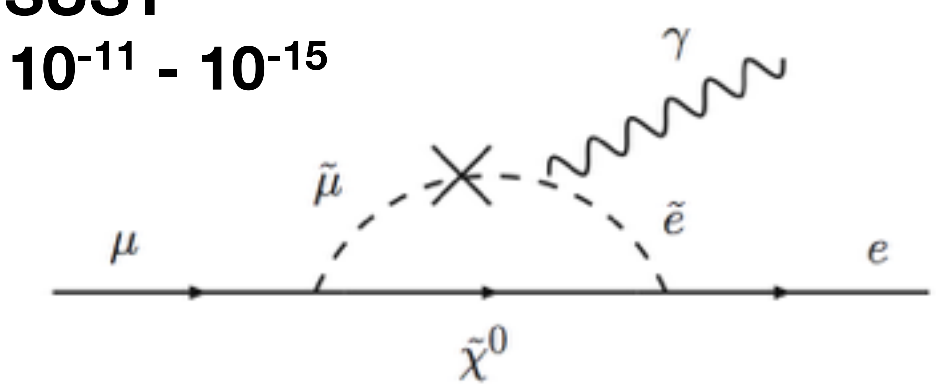
- Lepton Flavor conservation in the Standard Model is an *accidental symmetry*, arising from the particle content of the model

- Generally violated in most of New Physics models

Standard Model
BR < 10^{-54}



SUSY
BR ~ 10^{-11} - 10^{-15}

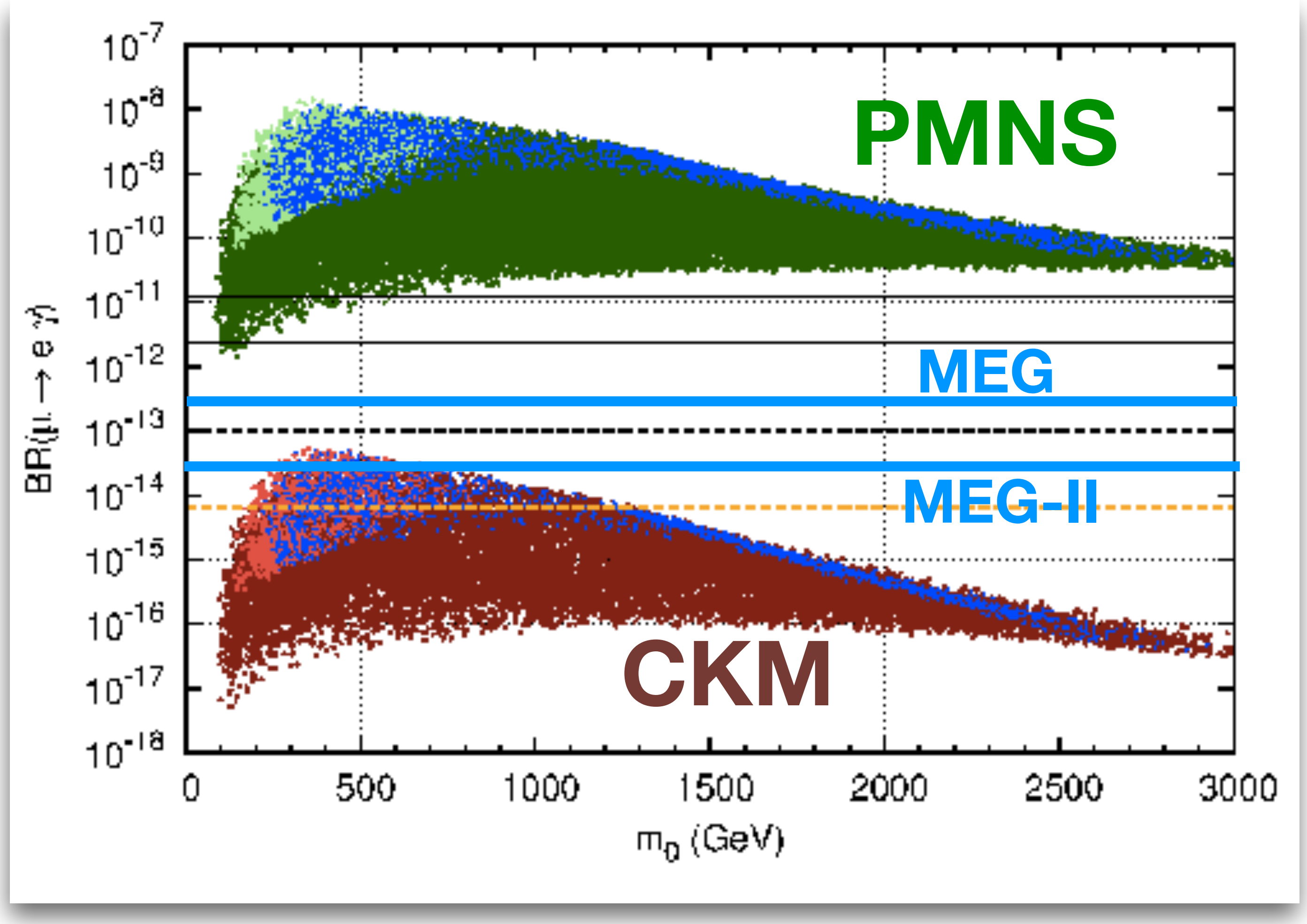


"Charged Lepton Flavor Violation (cLFV) is THE signature for New Physics"

— A. Schöning

cLFV and direct NP searches at the LHC

- cLFV rates strongly depend on the details of the flavor structure of new physics:
    - even within the same model, cLFV constraints can be much stronger or much weaker than LHC constraints, depending on the flavor structure that is chosen
    - LHC searches still leave a lot of place for cLFV

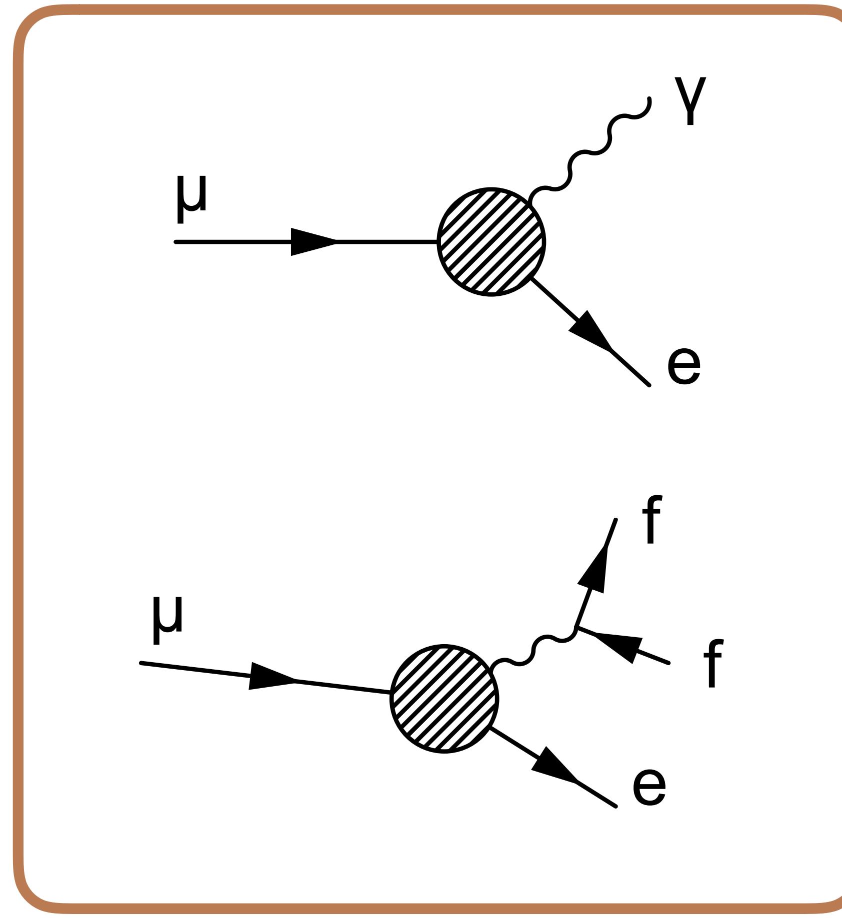


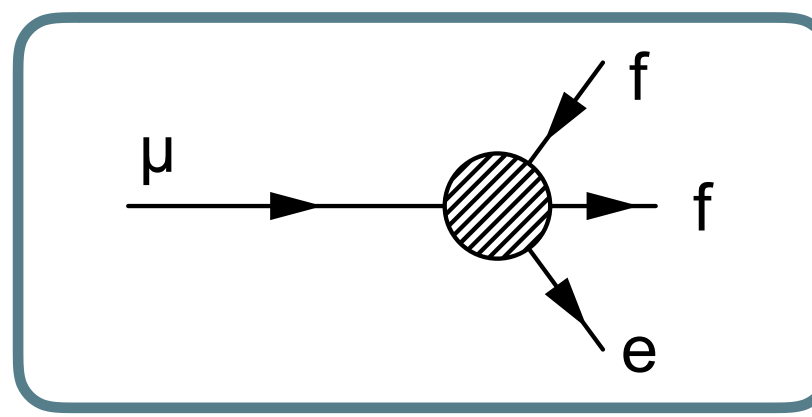
L. Calibbi et al., Eur. Phys. J. C72 (2012) 1863

STRONG COMPLEMENTARITY

cLFV searches in the muon sector - the naive view

- cLFV in the muon sector searched for decays (**μ -> e γ**, **μ -> e e e**) and **μ -> e conversion** in nuclei
- Effective Field Theory (EFT) approach:
  - **μ -> e γ** sensitive to **dipole operators**
  - **μ -> e e e** and **μ N -> e N** sensitive to both **dipole** and **4-fermion operators**



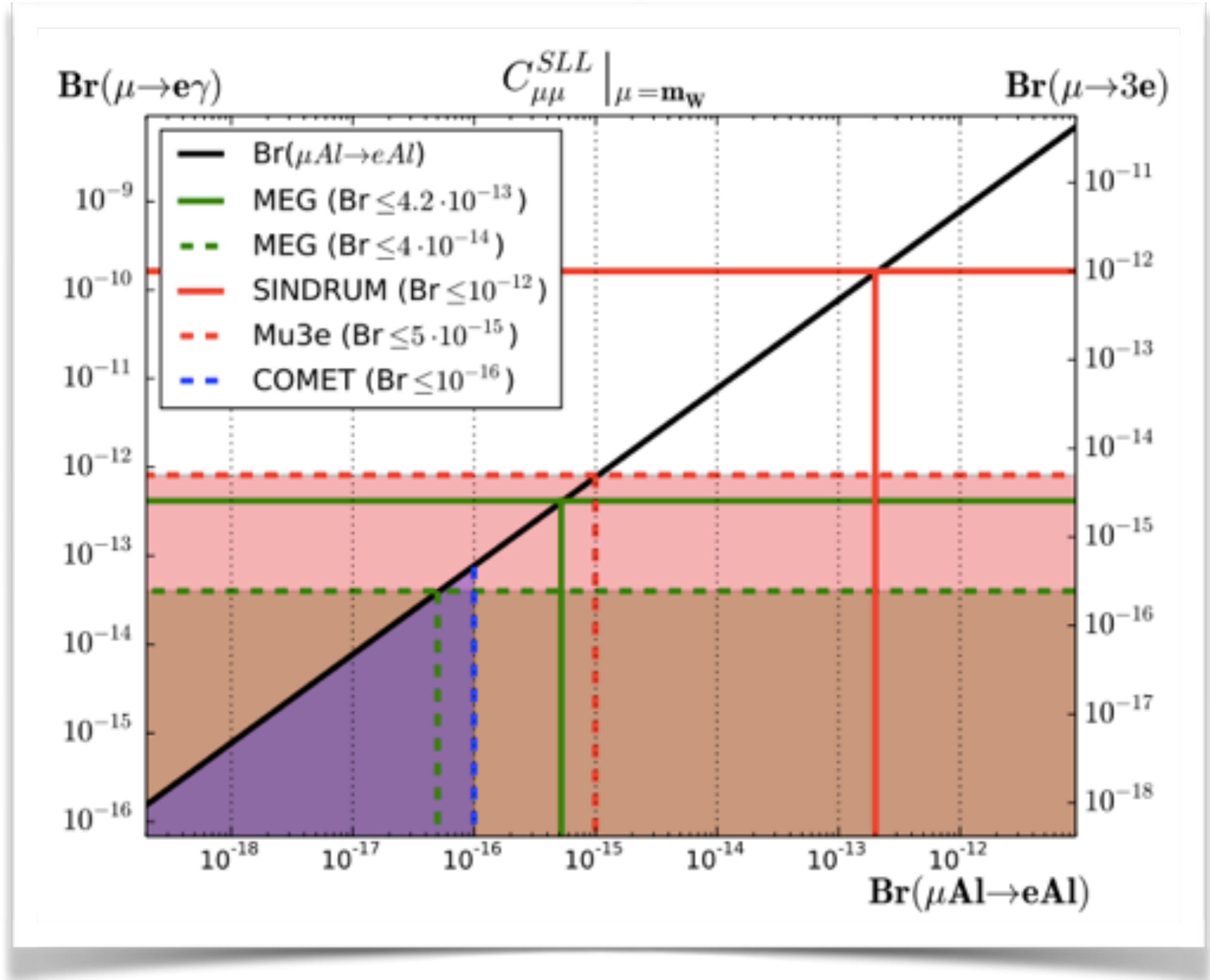


Naive conclusion: the upcoming μ -> e conversion experiments will overcome the muon decay experiments

cLFV searches in the muon sector - the full view

- Operators mix at the loop level:
  - **μ -> e γ** also sensitive to 4-fermion operators
  - **μ -> e γ** can give the strongest bound in some scenarios

STRONG COMPLEMENTARITY



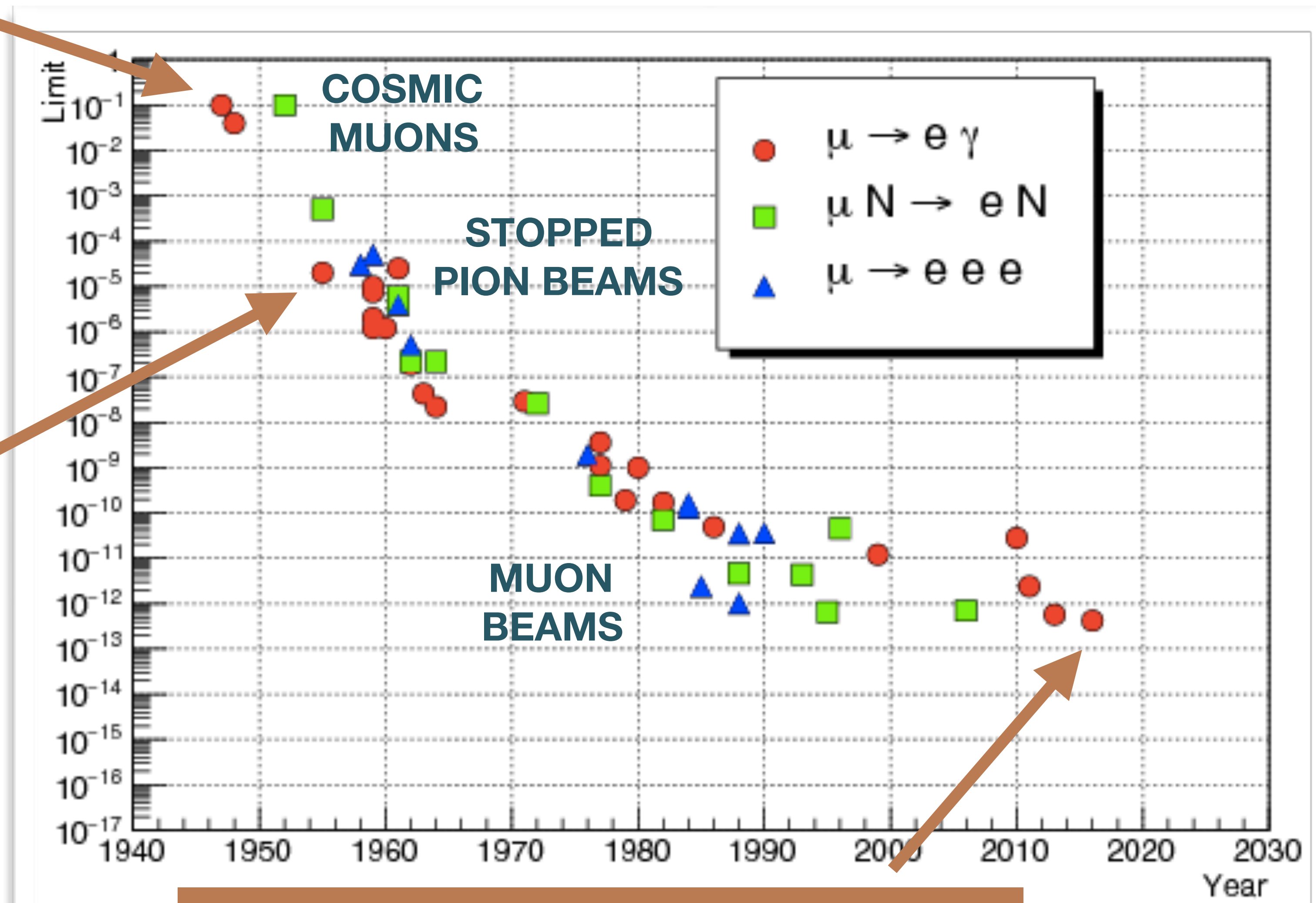
A. Crivellin et al., JHEP 1705 (2017) 117

Even in the era of the upcoming μ -> e conversion experiments, μ -> e γ (and μ -> e e e) will continue to play a crucial role

History of cLFV searches

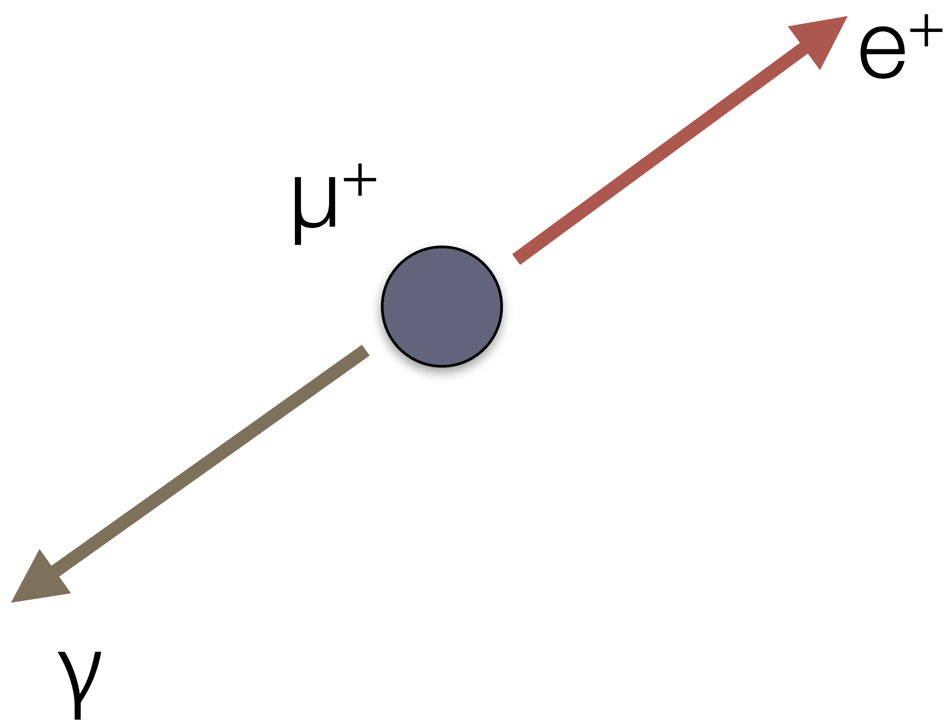
Hincks & Pontecorvo
[Phys. Rev. 73 (1948) 257]
muon is not an "excited electron"

Lokanathan & Steinberger
[Phys. Rev. A 98 (1955) 240]
lepton flavors



MEG Experiment
[Eur.Phys.J. C76 (2016) 8, 434]
BR(μ -> e γ) < 4.2 x 10^-13

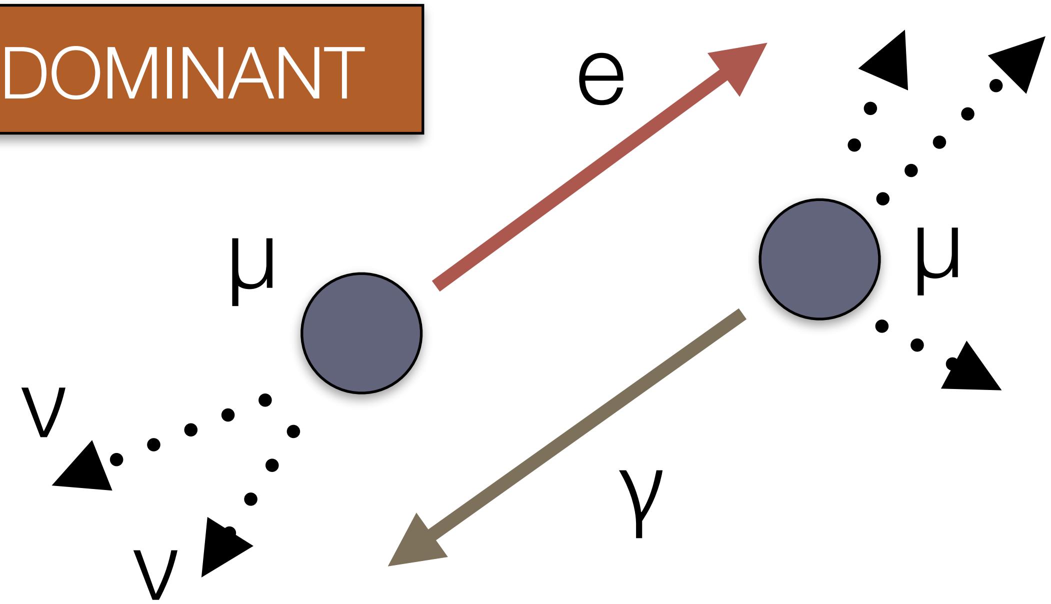
μ -> e γ searches



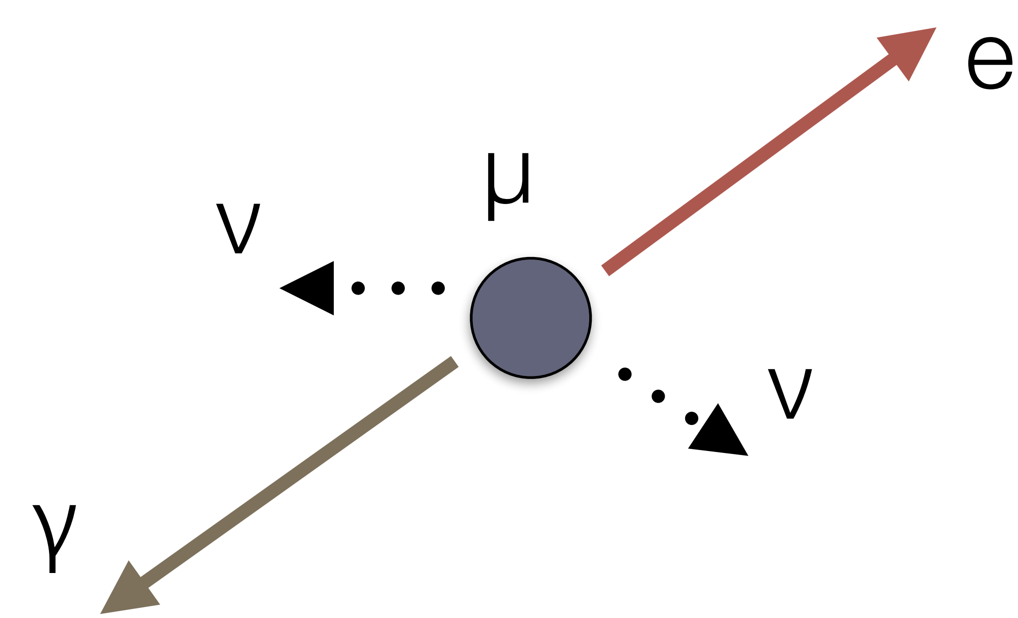
Positron and photon are **monochromatic** (52.8 MeV), **back-to-back** and produced at the **same time**;

Accidental Background

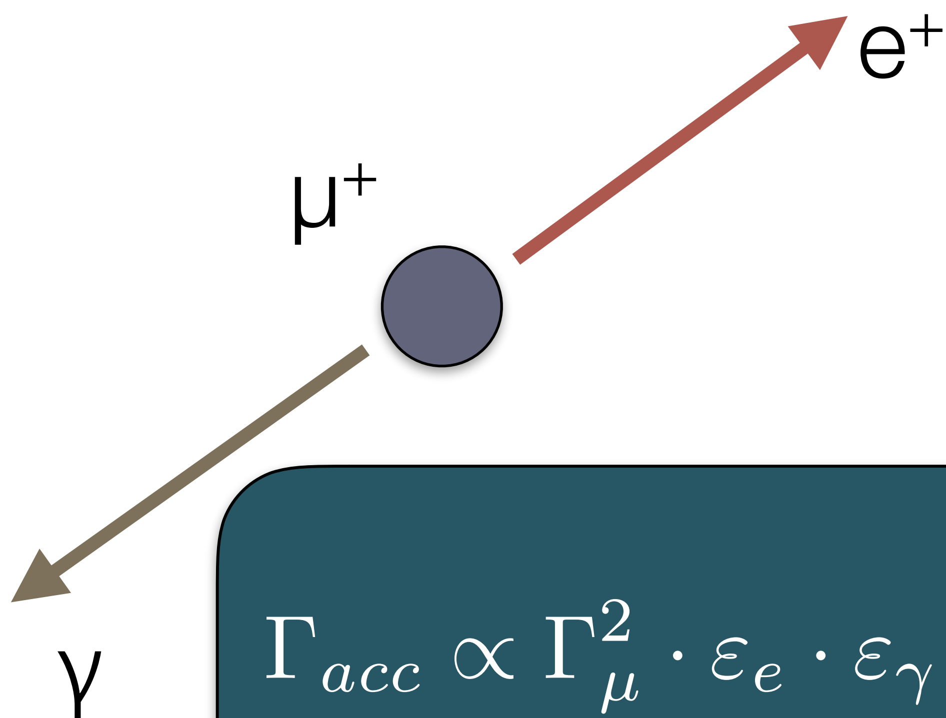
DOMINANT



Radiative Muon Decay (RMD)



μ -> e γ searches



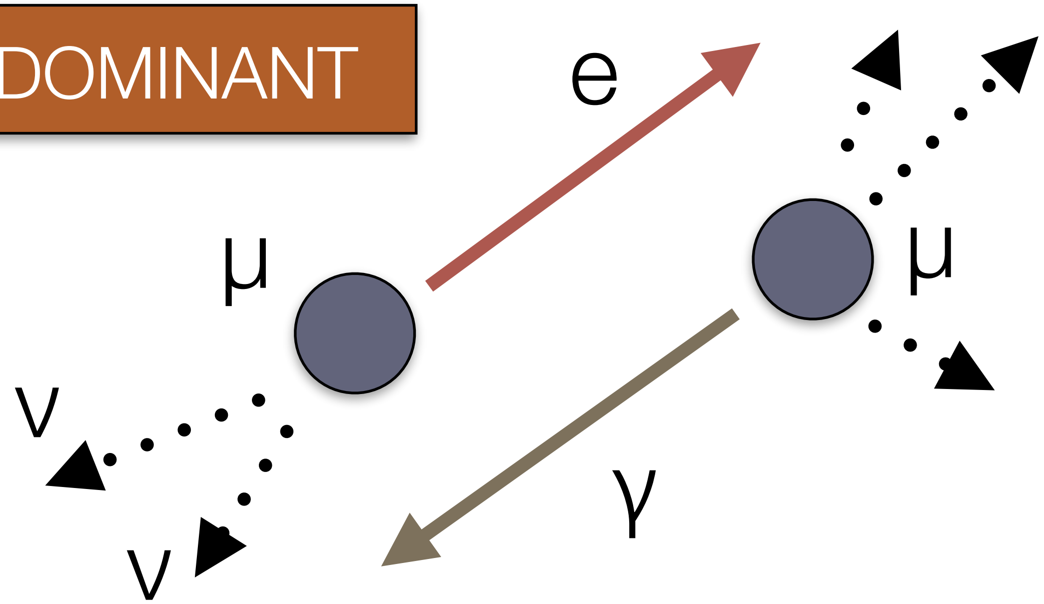
Positron and photon are **monochromatic** (52.8 MeV), **back-to-back** and produced at the **same time**;

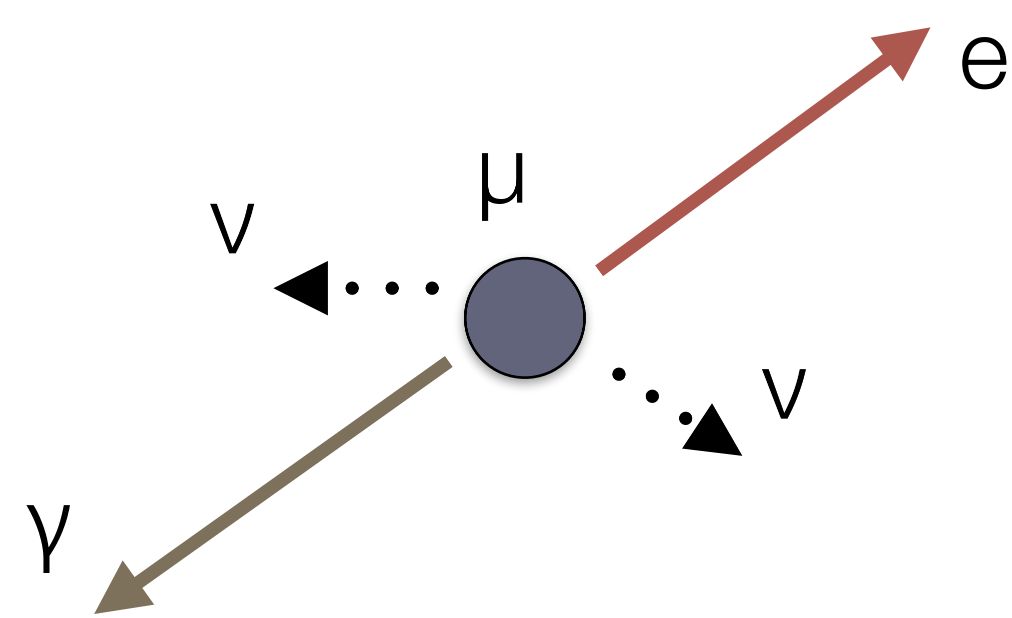
$$\Gamma_{acc} \propto \Gamma_{\mu}^{2} \cdot \varepsilon_{e} \cdot \varepsilon_{\gamma} \cdot \delta E_{e} \cdot (\delta E_{\gamma})^{2} \cdot (\delta \Theta_{e\gamma})^{2} \cdot \delta T_{e\gamma}$$

Accic

ay (RMD)

DOMINANT

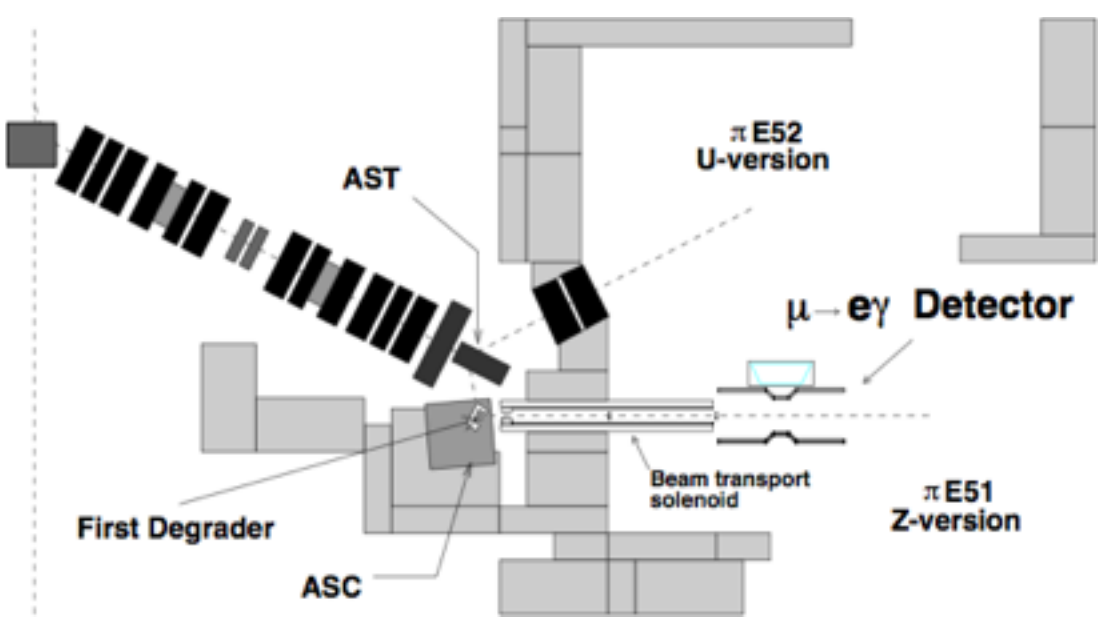




The most intense DC muon beam in the world

- The ring cyclotron at PSI (Villigen, CH) serves the most intense DC muon beam lines in the world

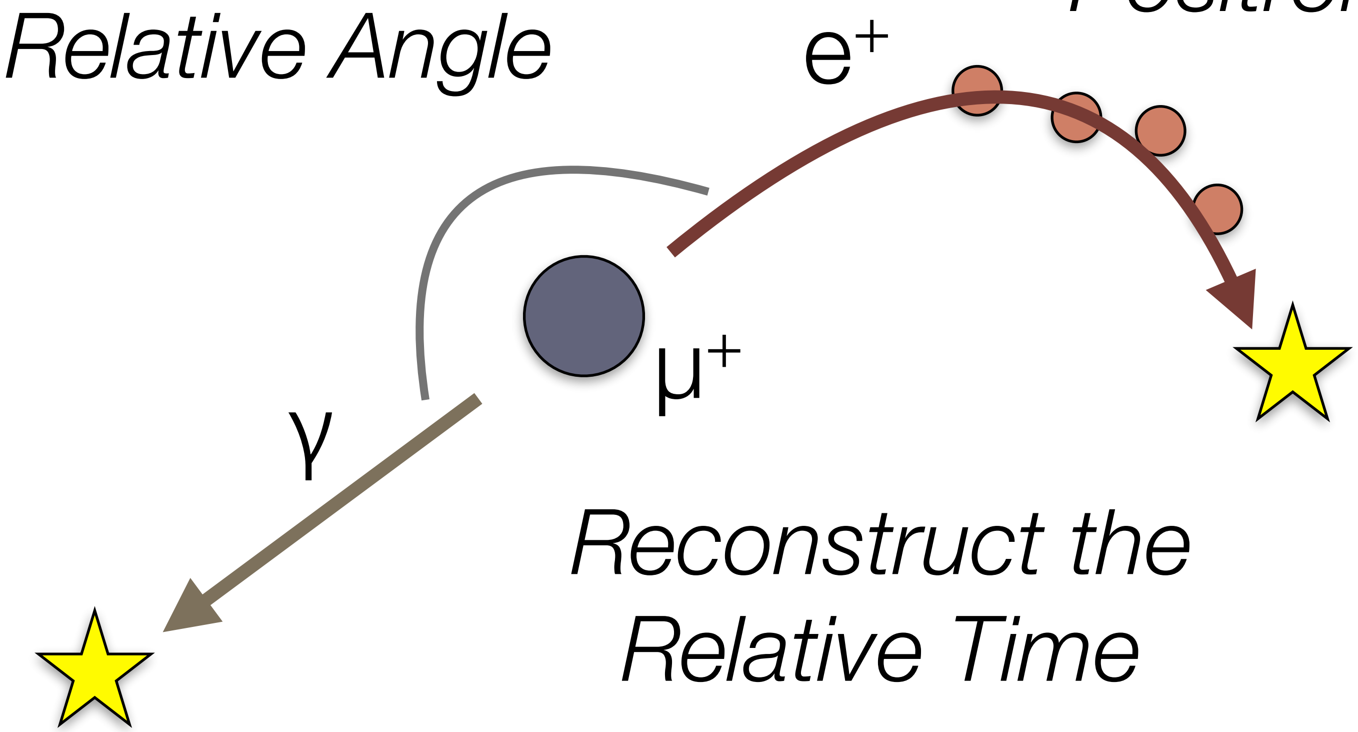
πE5 - up to 10^8 μ/s



Ingredients for a search of μ -> e γ

Reconstruct the
Positron Energy

Reconstruct the
Relative Angle



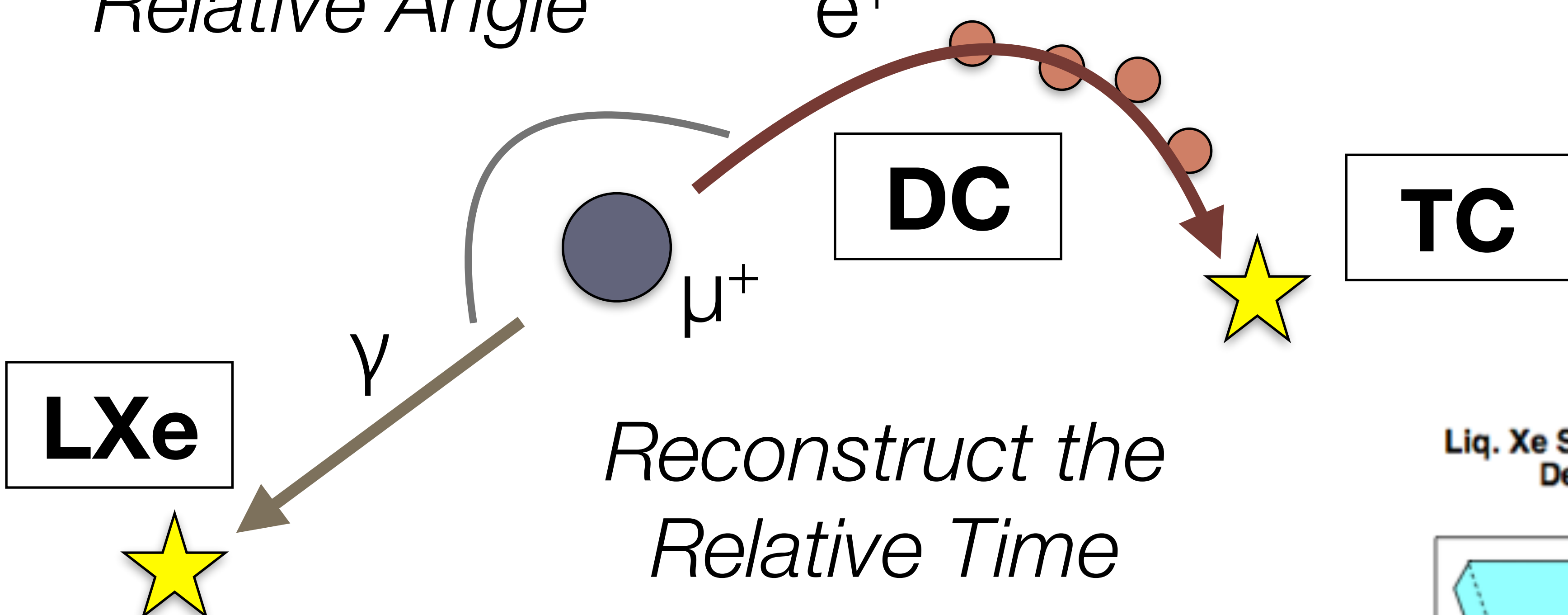
Reconstruct the
Relative Time

Reconstruct the
Photon Energy

The MEG Experiment

Reconstruct the Relative Angle

Reconstruct the Positron Energy



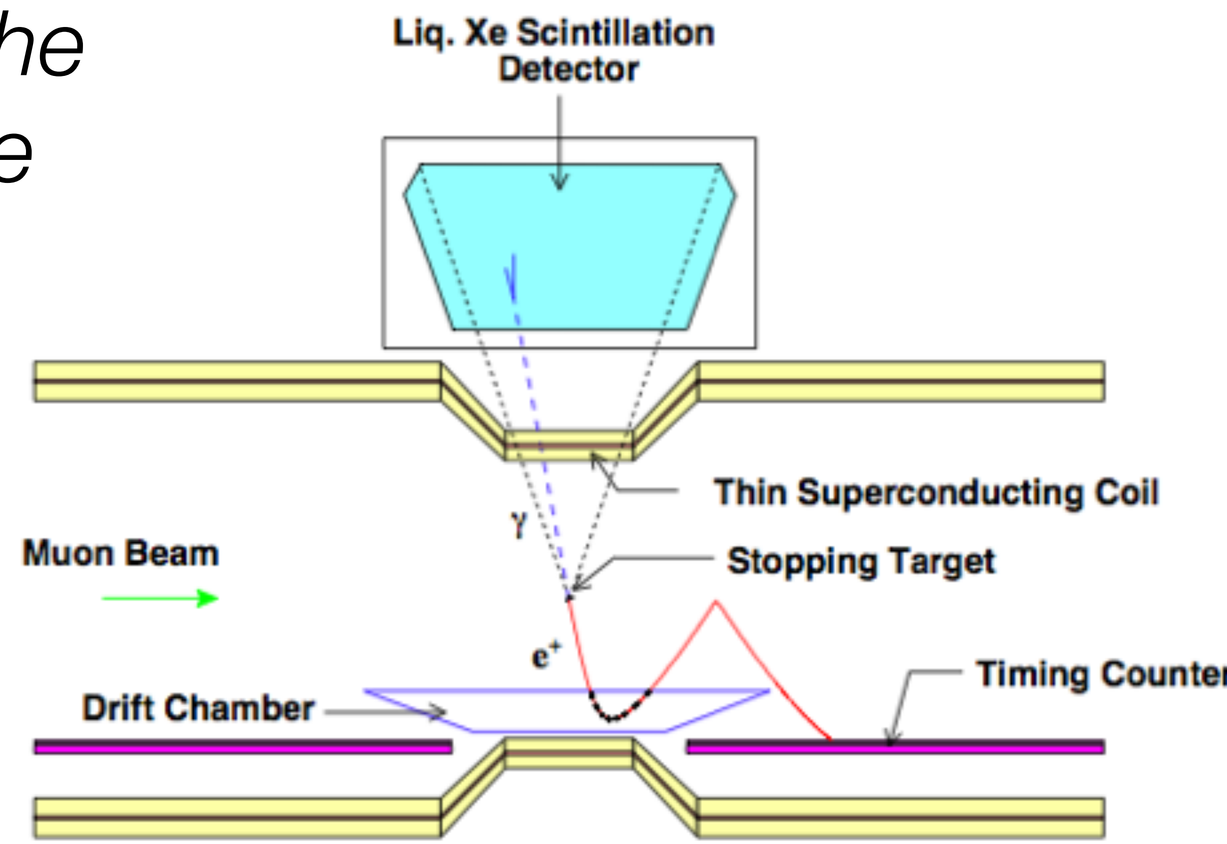
Reconstruct the Relative Time

Reconstruct the Photon Energy

LXe calorimeter

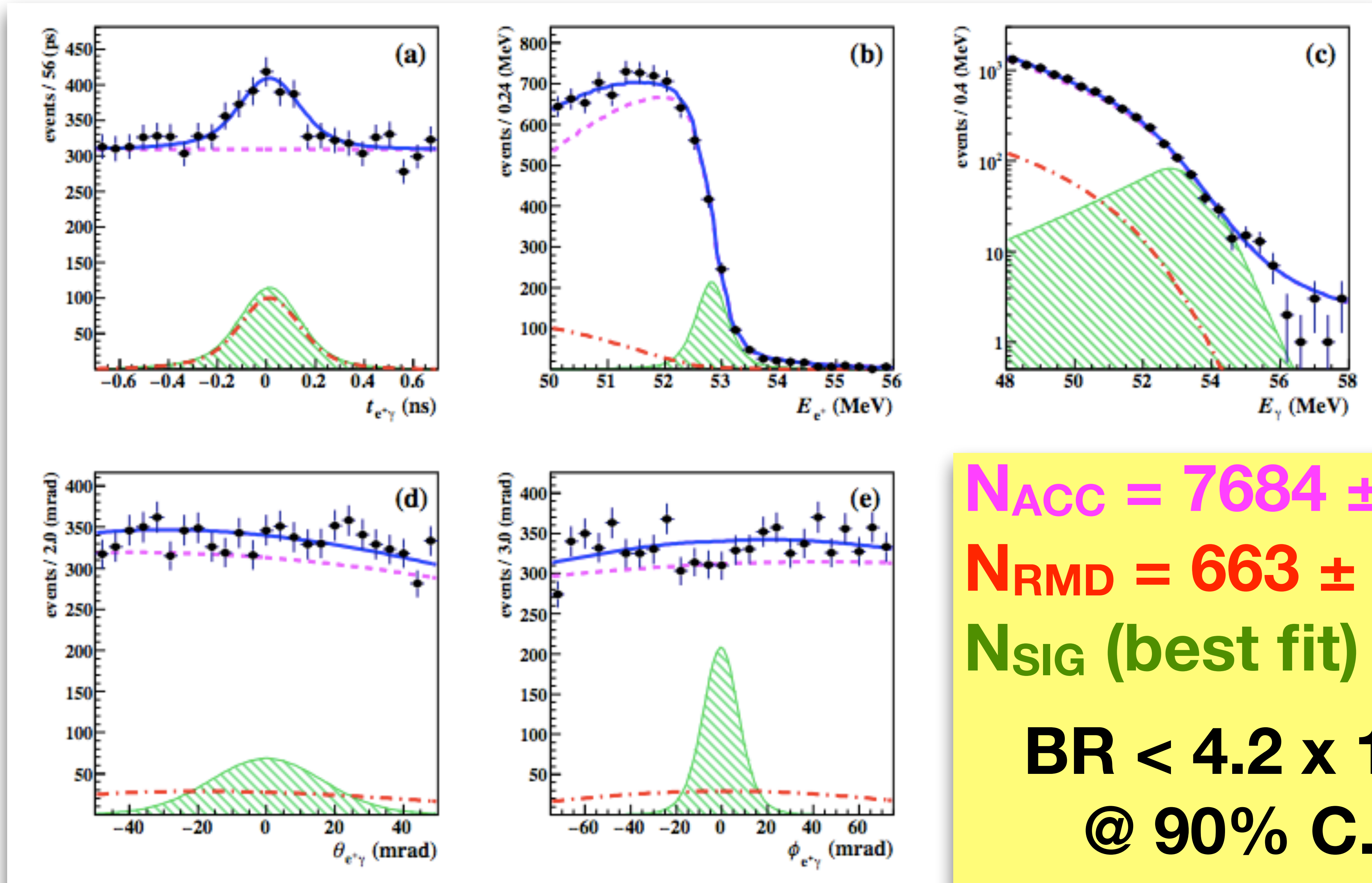
16 Drift Chambers in a magnetic field

30 scintillating bars for timing & trigger



The final MEG result (I)

7.5 x 10^{14} μ on target



N_{ACC} = 7684 ± 103

N_{RMD} = 663 ± 59

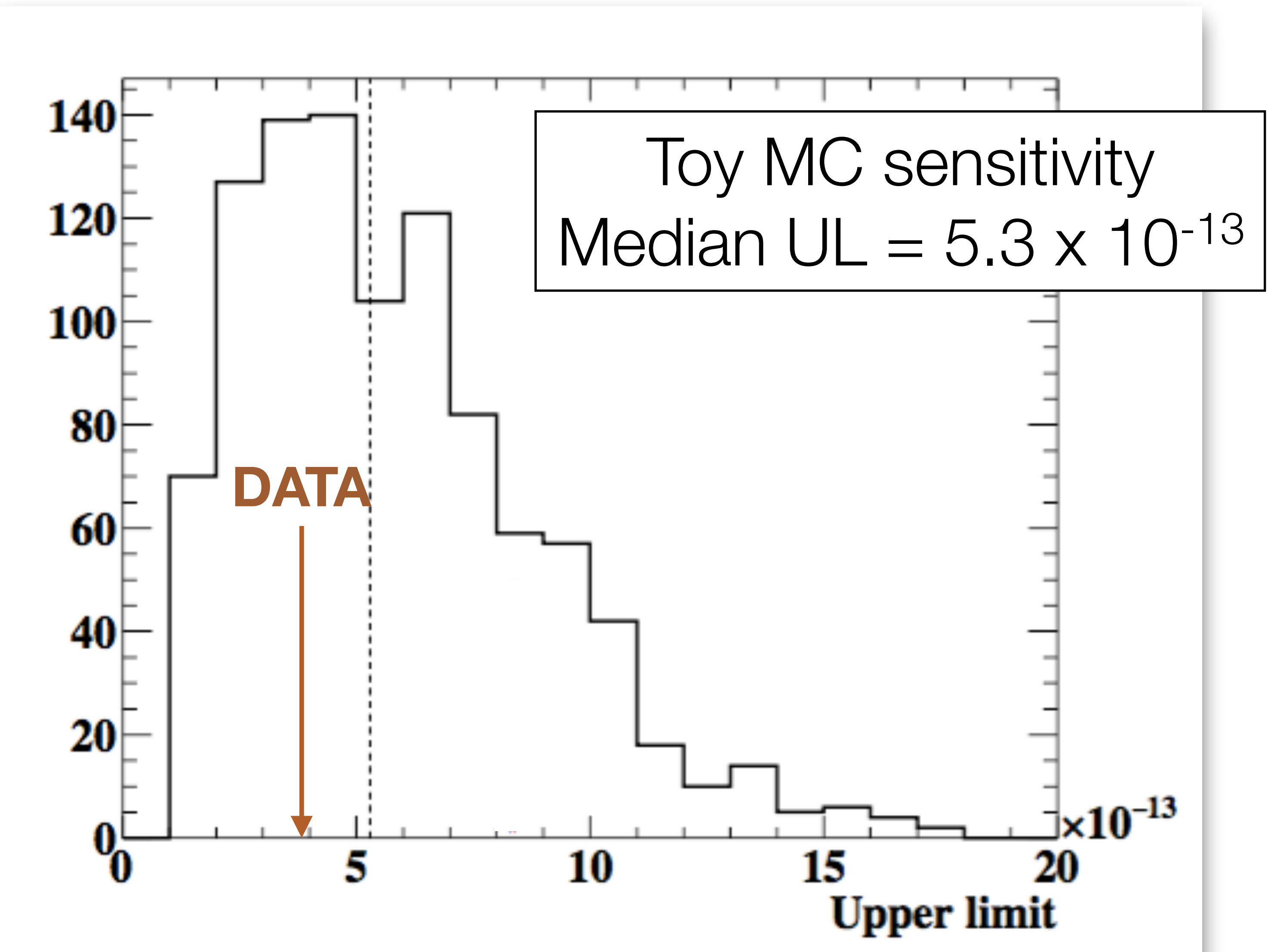
N_{SIG} (best fit) = -2.2

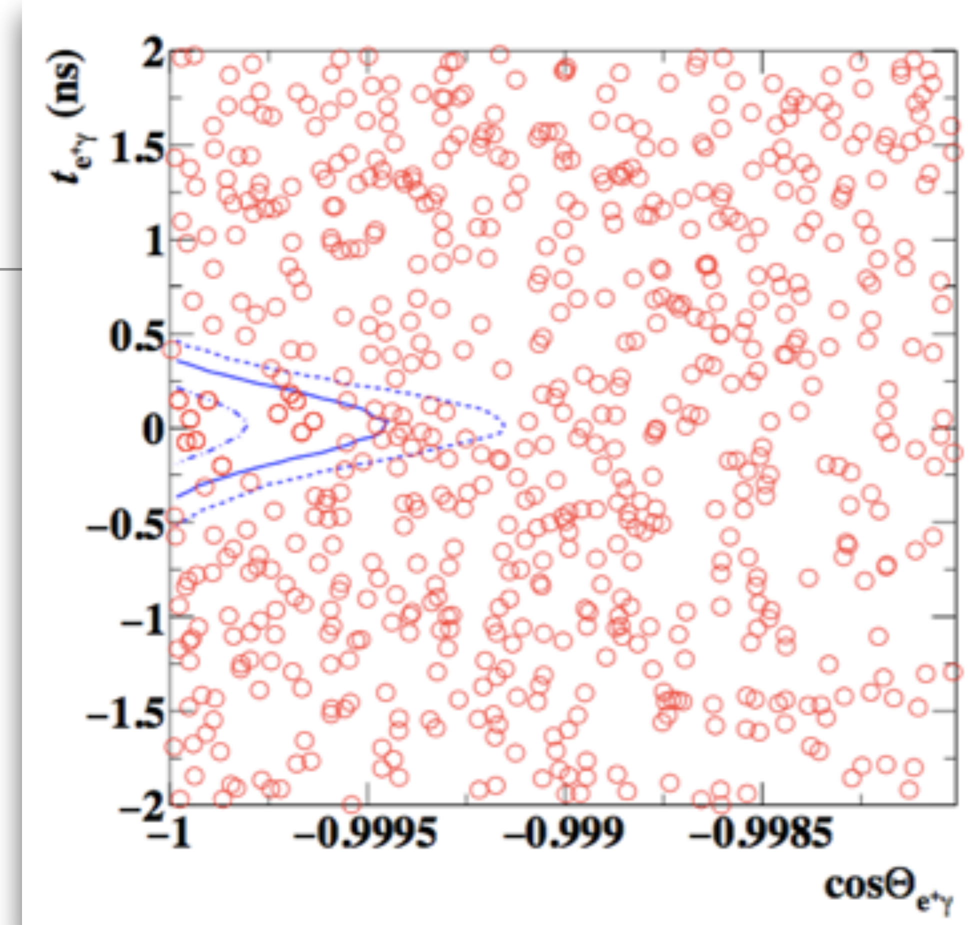
BR < 4.2 x 10^{-13}
@ 90% C.L.

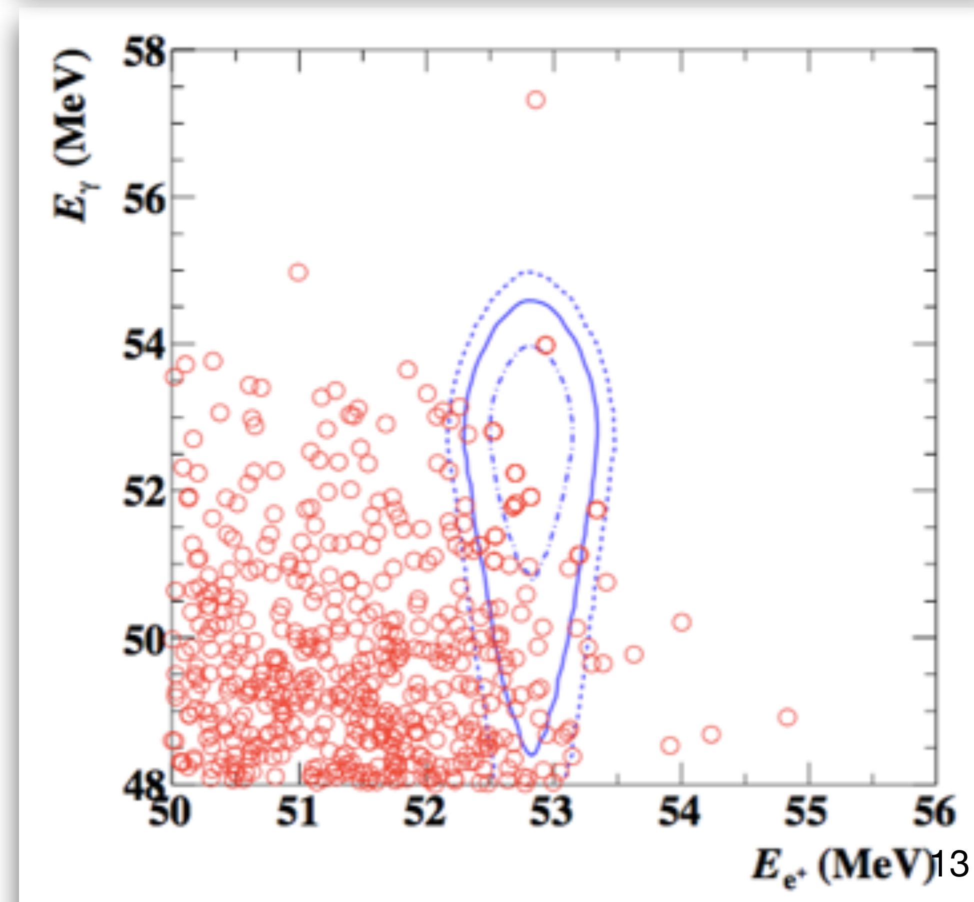
Eur. Phys. J. C76 (2016) no. 8, 434

Magnified signal (BR = 4 x 10^{-11})

The final MEG result (II)







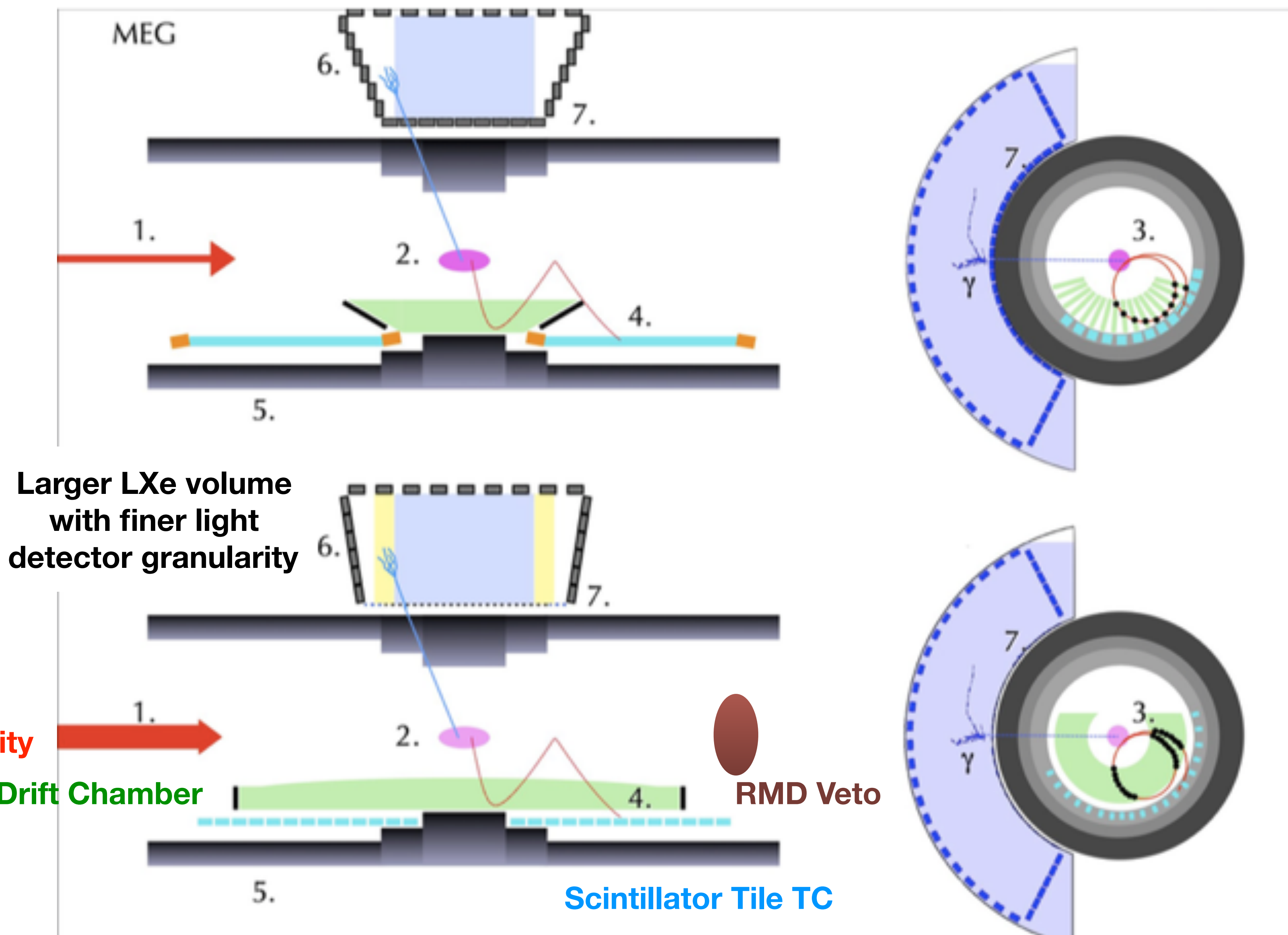
MEG-II

- The MEG experiment is undergoing an upgrade that involves all sub-detectors

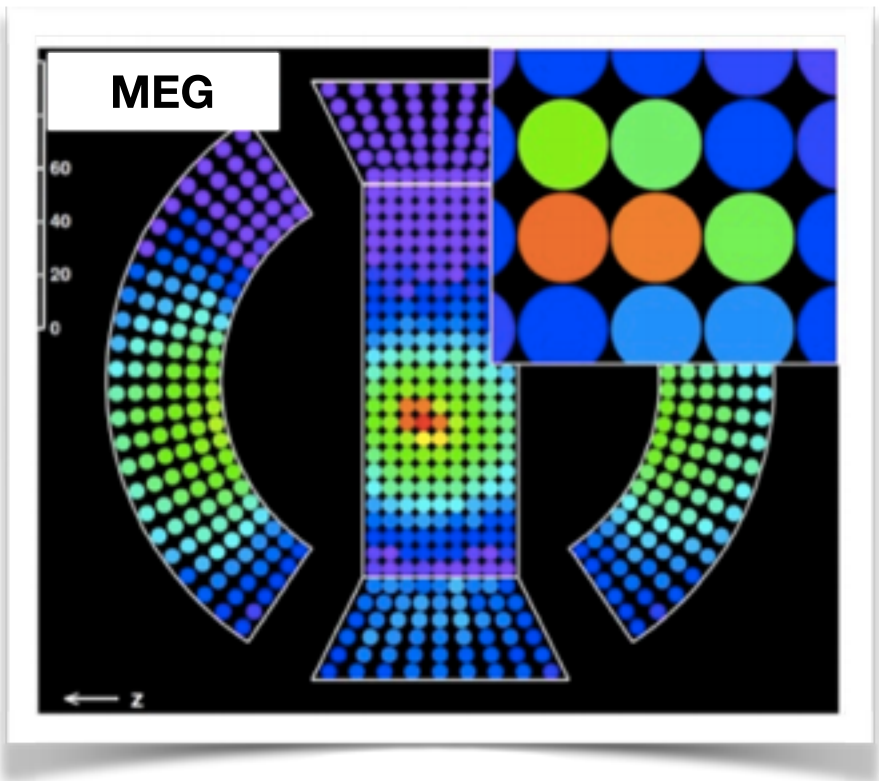
Eur. Phys. J. C78 (2018) no.5, 380

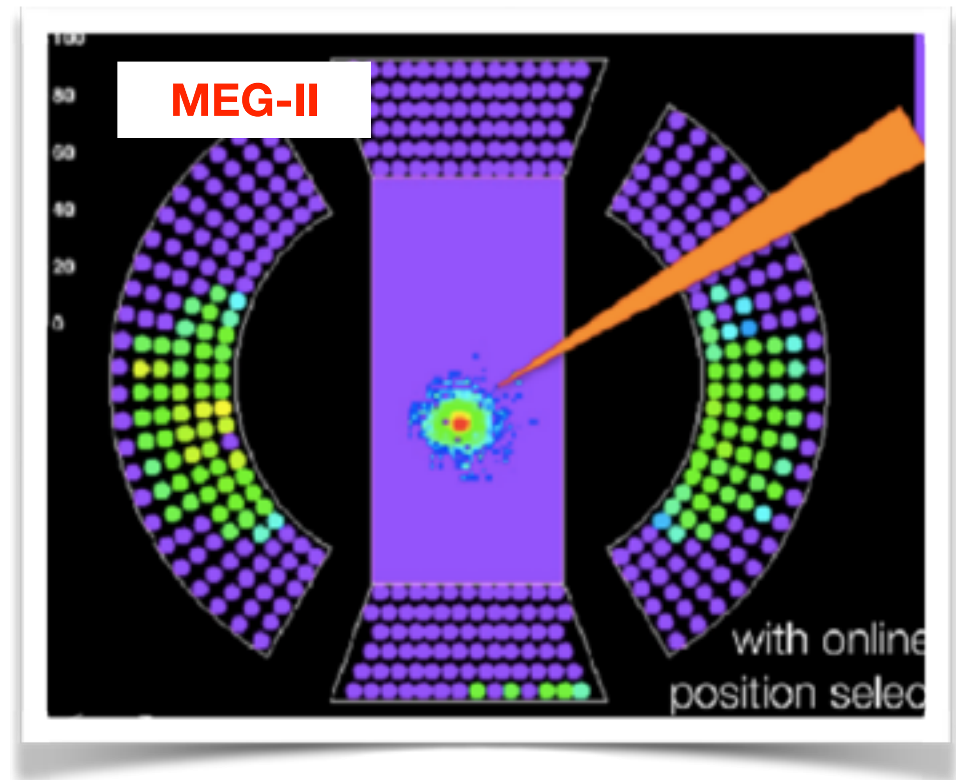
First physics run expected in 2020

UL ~ 6 x 10^{-14} in 3 years of run



MEG-II Highlights - The LXe Calorimeter

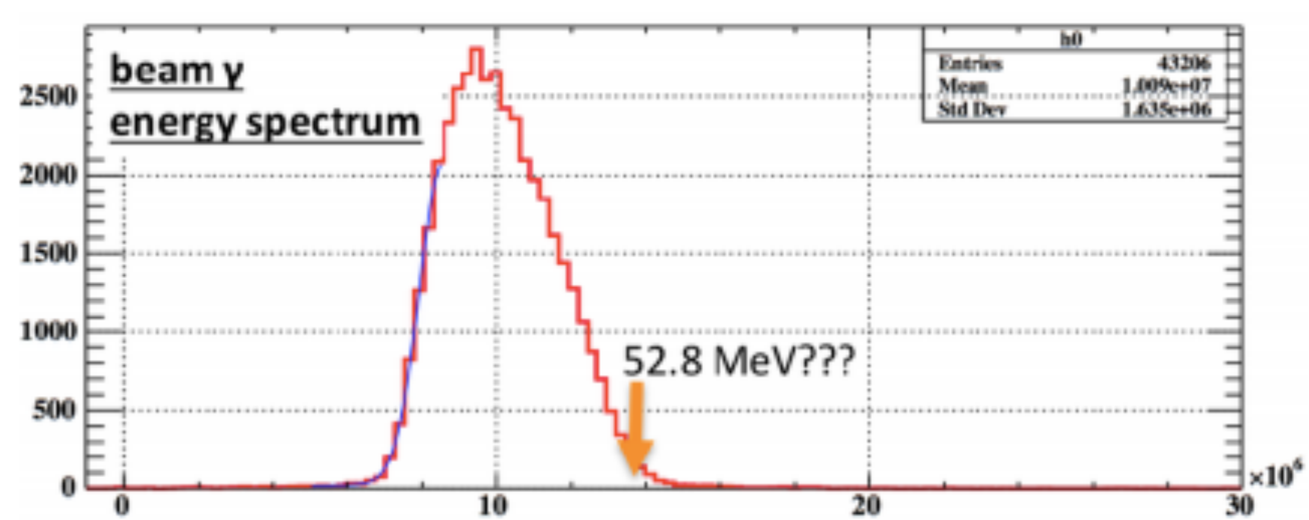




First events/spectra from 2017 data

We developed large-area (12x12 mm^2), UV-sensitive MPPCs to cover the inner face of the LXe calorimeter

Better Resolution, better pile-up rejection

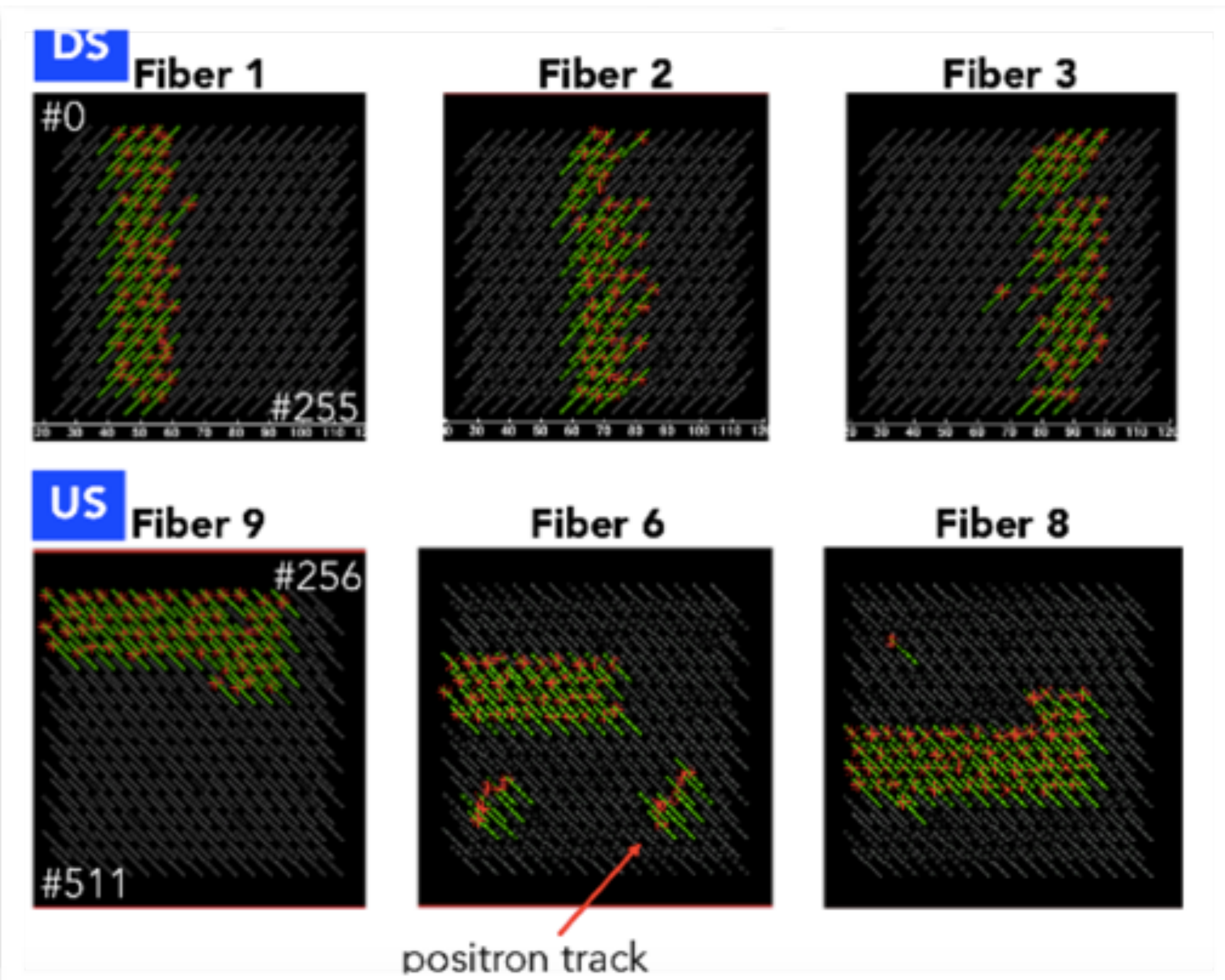


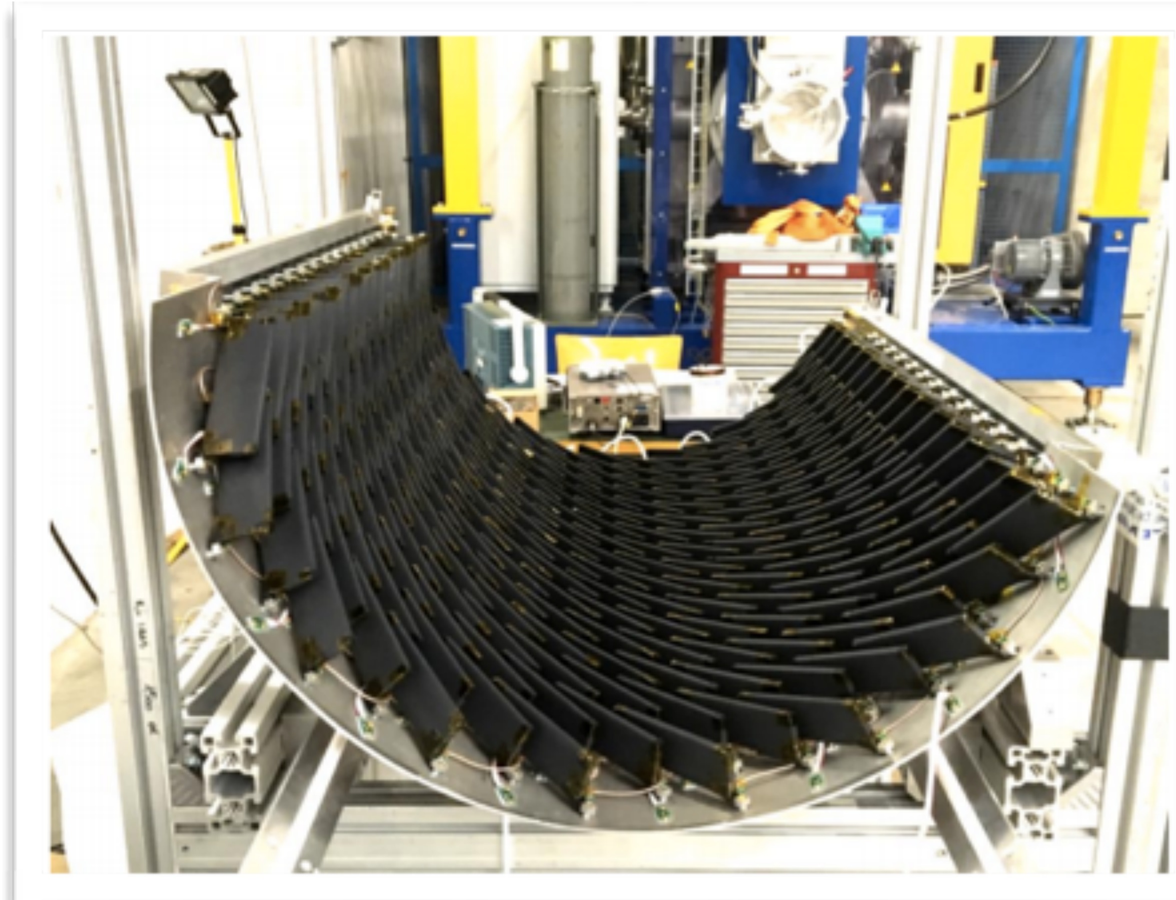
$\sigma_E \sim 1\%$, $\sigma_{position} \sim 2/5$ mm (x,y/z)

MEG-II Highlights - The Timing Counters

5mm-thick Scintillator Tiles read out by 3x3 mm^2 SiPM

Detector completed, data taken in 2017 and 2018





Calibration with dedicated laser

MEG-II Highlights - The Timing Counters

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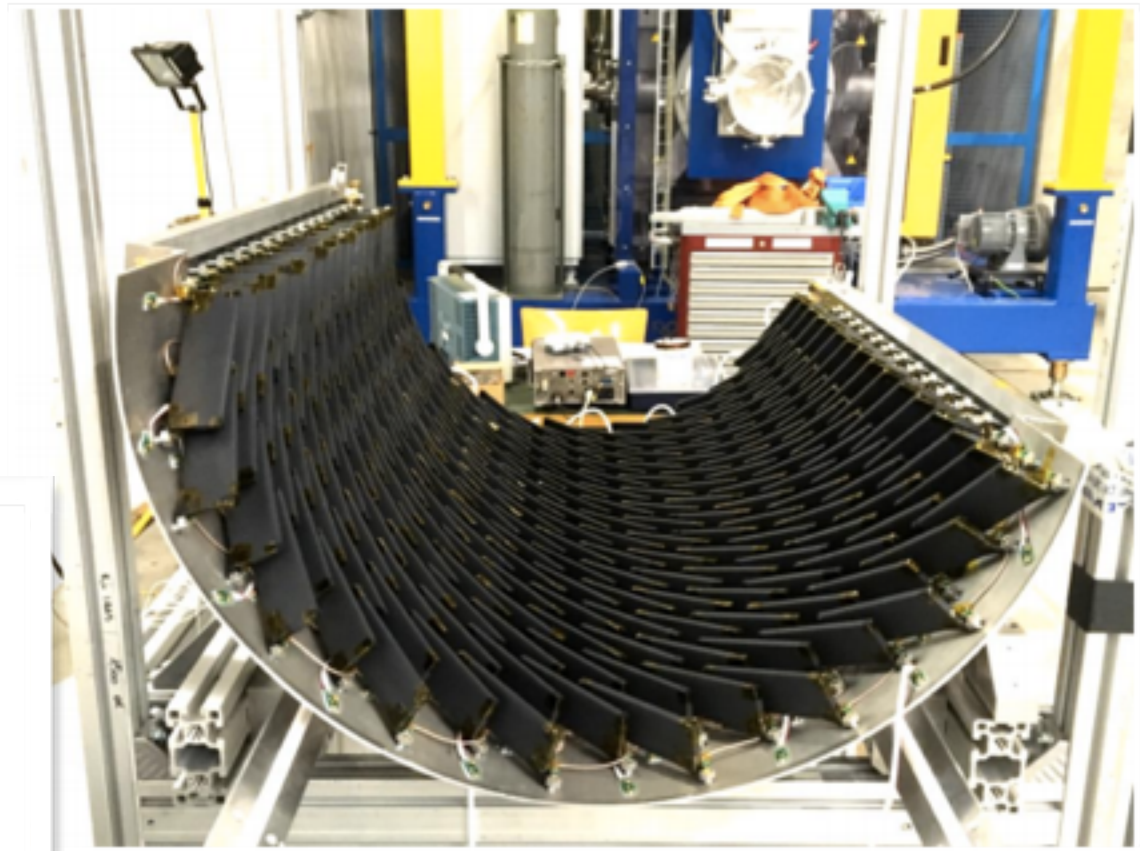
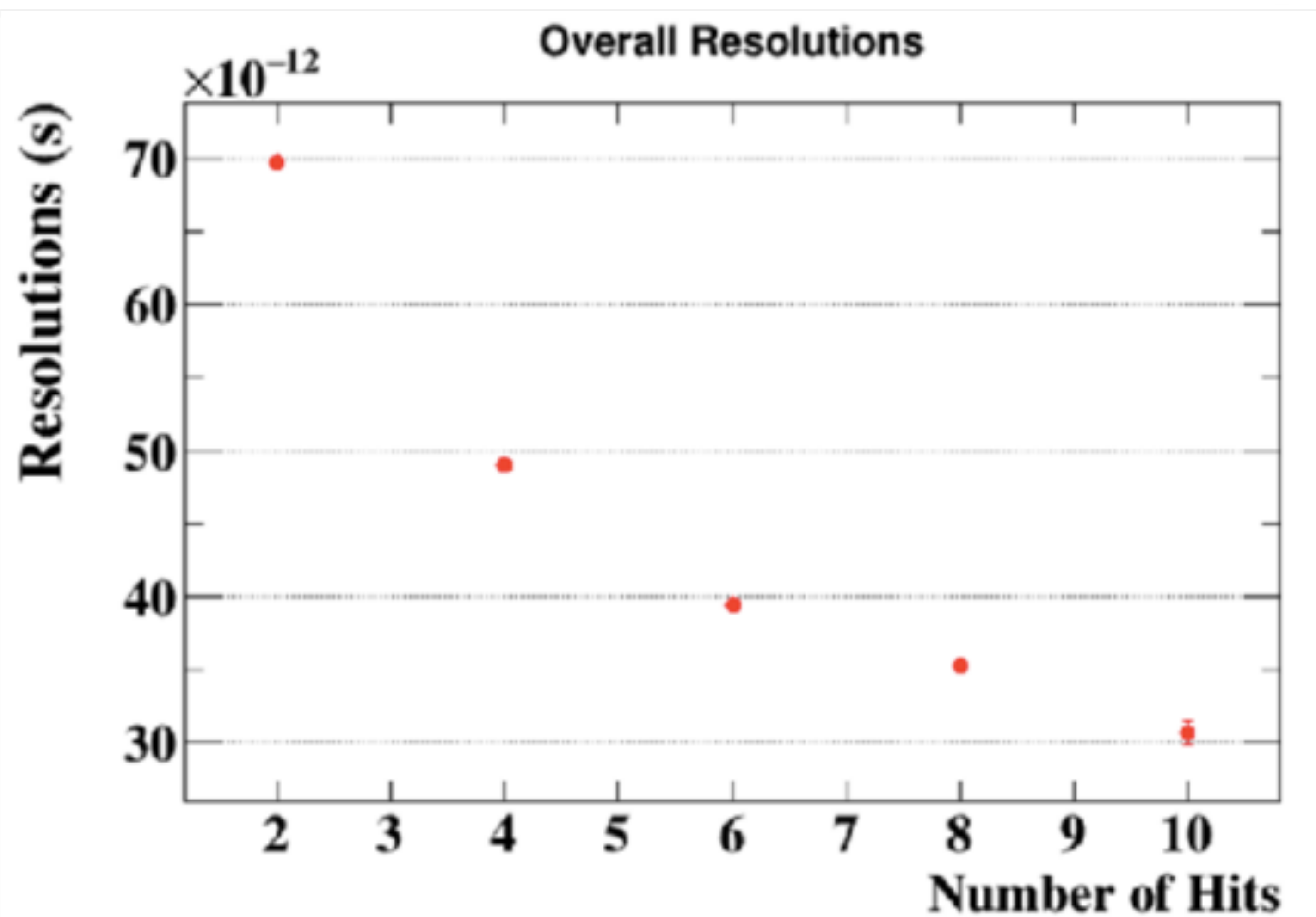
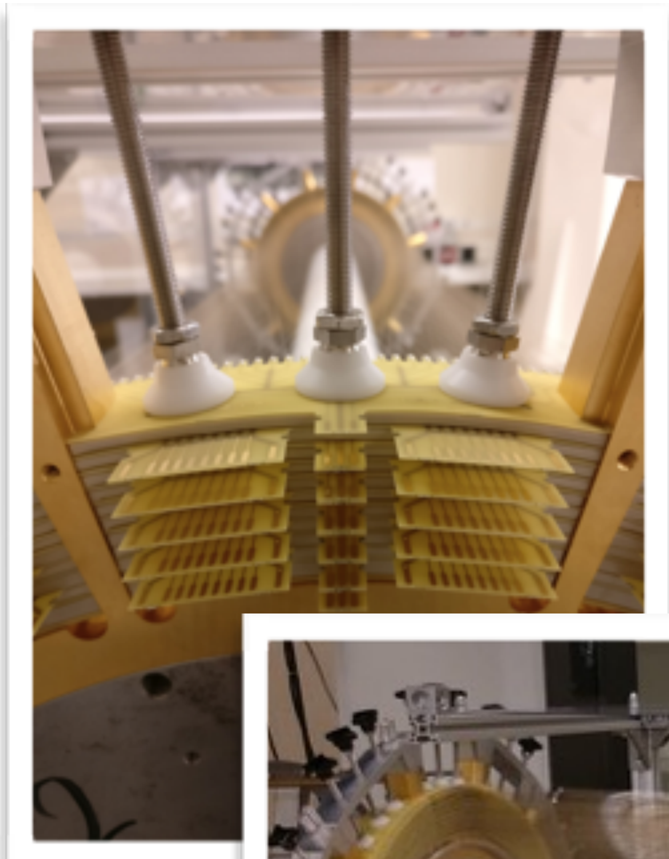




$\sigma_T \sim 35$ ps

Already reached the design resolution

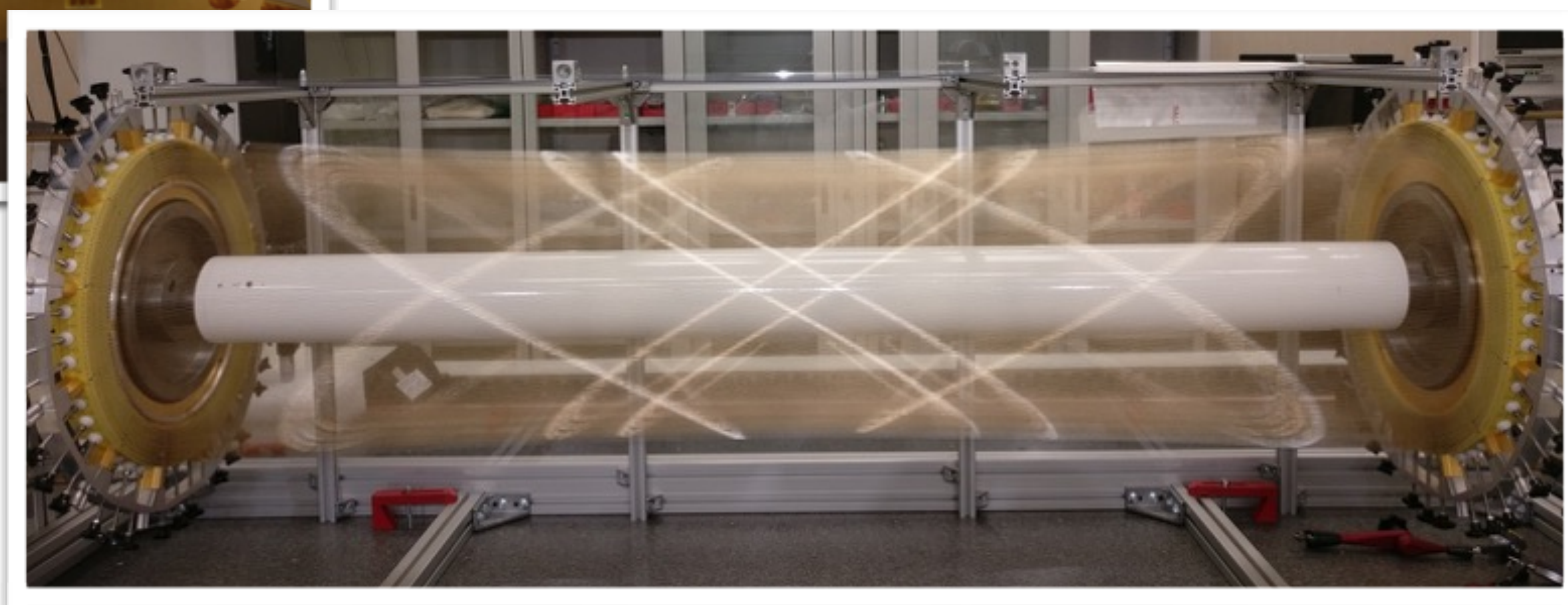
MEG-II Highlights - The Drift Chamber



The challenge: minimal material budget (to reduce MS of 50 MeV e^+) and **very high granularity** (to cope with the high rate) —> small cells (down to < 6 mm) + extremely thin wires (20 μm W(Au) + 40-50 μm Al(Ag))

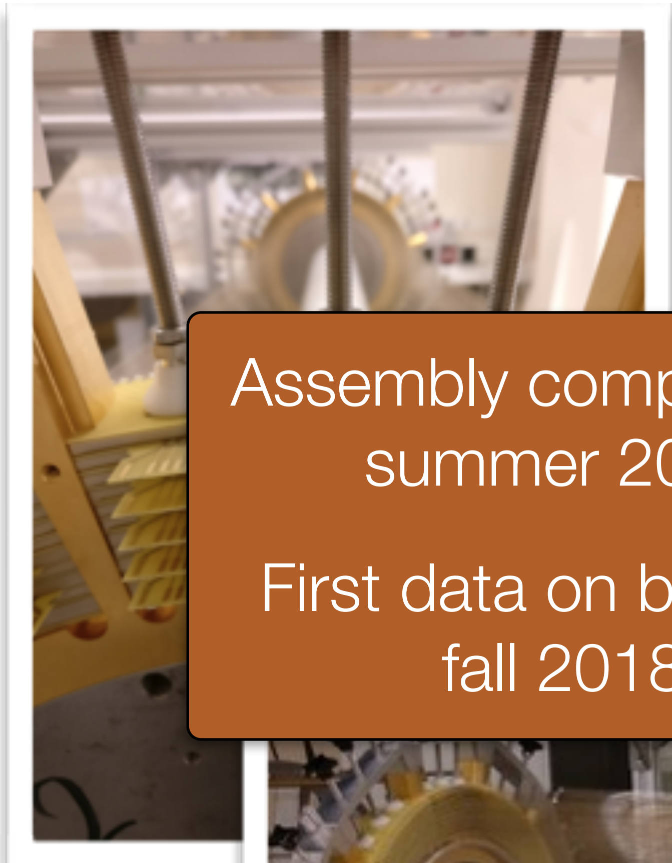
Innovative wiring technique (no feedthroughs)

Severe problems of wire fragility in presence of contaminants + humidity



σ_E ~ 130 keV, σ_{angles} ~ 5 mrad, 2x larger positron efficiency

MEG-II Highlights - The Drift Chamber



The challenge: minimal material budget (to reduce MS of 50 MeV e^+) and **very high granularity** (to cope with the high rate) —> small cells (down to < 6 mm) + extremely thin wires (20 μm W(Au) + 40-50 μm Al(Ag))

Innovative wiring technique (no feedthroughs)

problems of wire fragility in presence of contaminants + humidity

Assembly completed in summer 2018

First data on beam in fall 2018

σ_E ~ 130 keV, σ_{angles} ~ 5 mrad, 2x larger positron efficiency

MEG-II Highlights - The Drift Chamber

- Low wire elongation in 2018 (50% of elastic limit) to limit the impact of wire fragility —> electrostatic stability problems (inner layers could not reach the working point)

Layer	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
9 (1500 V)	1500	1500	1500	1500	1500	1430	1500	1500	1500	1500	1500	1500
8 (1510 V)	1510	1510	1510	1500	1510	1510	1510	1510	1510	1510	1510	1510
7 (1520 V)	1520	1520	1520	1520	1520	1520	1520	1520	1520	1520	1520	1520
6 (1530 V)	1530	1530	1530	1530	1530	1530	1530	1530	1530	1530	1530	1530
5 (1540 V)	1540	1540	1540	1540	1540	1540	1540	1540	1540	1540	1540	1540
4 (1550 V)	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550
3 (1560 V)	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560
2 (1570 V)	1570	1570	1570	1570	1570	1570	1570	1570	1570	1570	1570	1570
1 (1580 V)	1580	1580	1580	1580	1580	1580	1580	1580	1580	1580	1580	1580

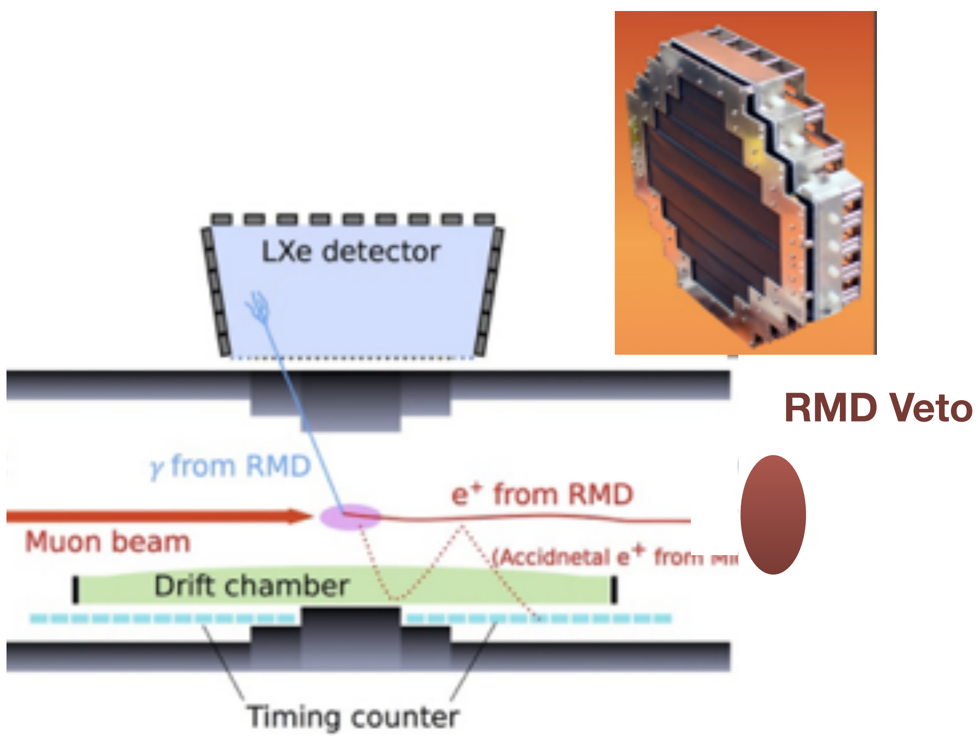
Working point + 100V

green = goal reached

Elongation increased in Spring 2019

New HV tests show that all the chamber can now be operated at the proper working point (1400-1500 V, 5 x 10^5 gain) with 100 V safety margin

RDC & Target monitoring



50% of acc. background photons come from RMD w/ positron along the beam line

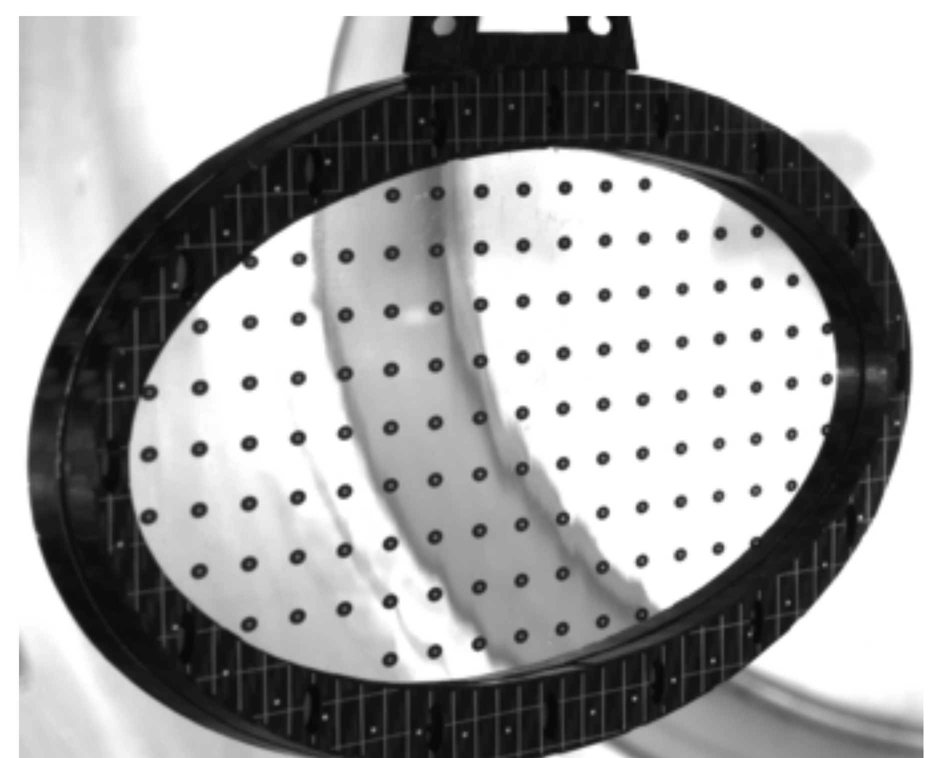
Can be vetoed by detecting the positron in coincidence with the photon

A new detector (LYSO + plastic scint.) built and tested in 2017 -> 16% better sensitivity

The target position in MEG-II has to be known with an accuracy ~ 100 μm to not compromise the angular resolution

A system of photo cameras has been installed to monitor the target position

<< 100 μm resolution reached



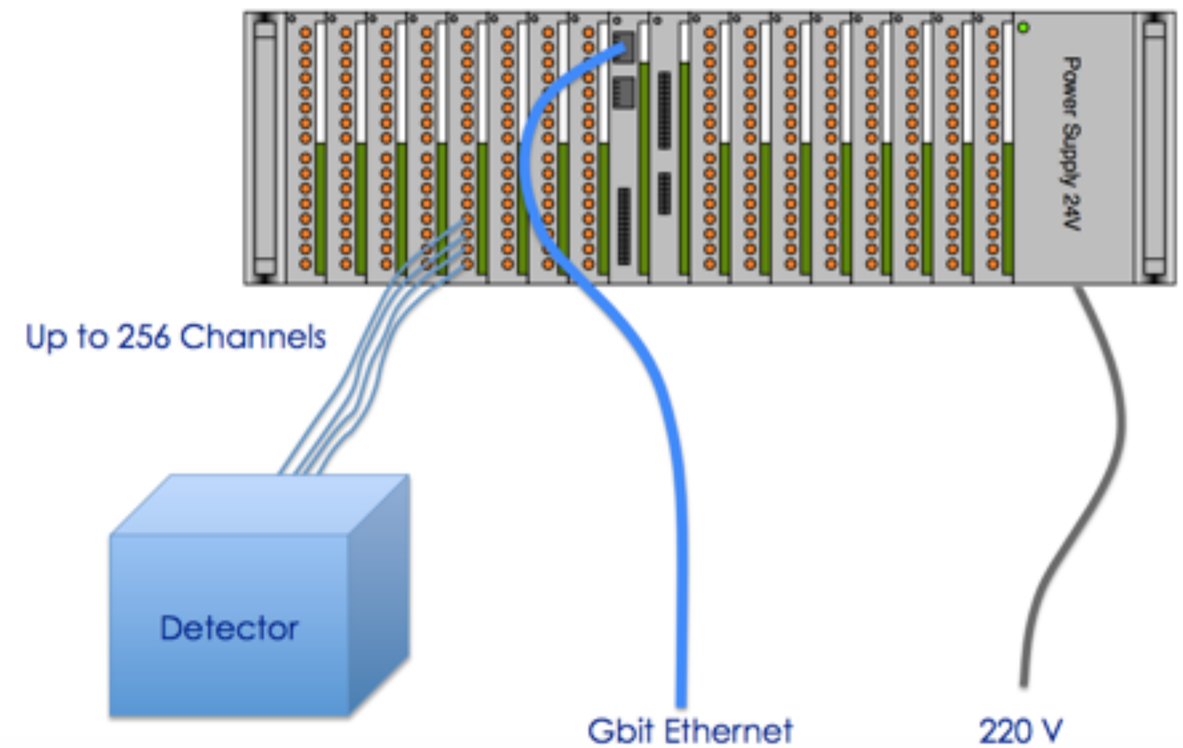
MEG-II Highlights - RDC, DAQ, Trigger

Trigger and DAQ will be integrated in a single, compact system (WaveDAQ)

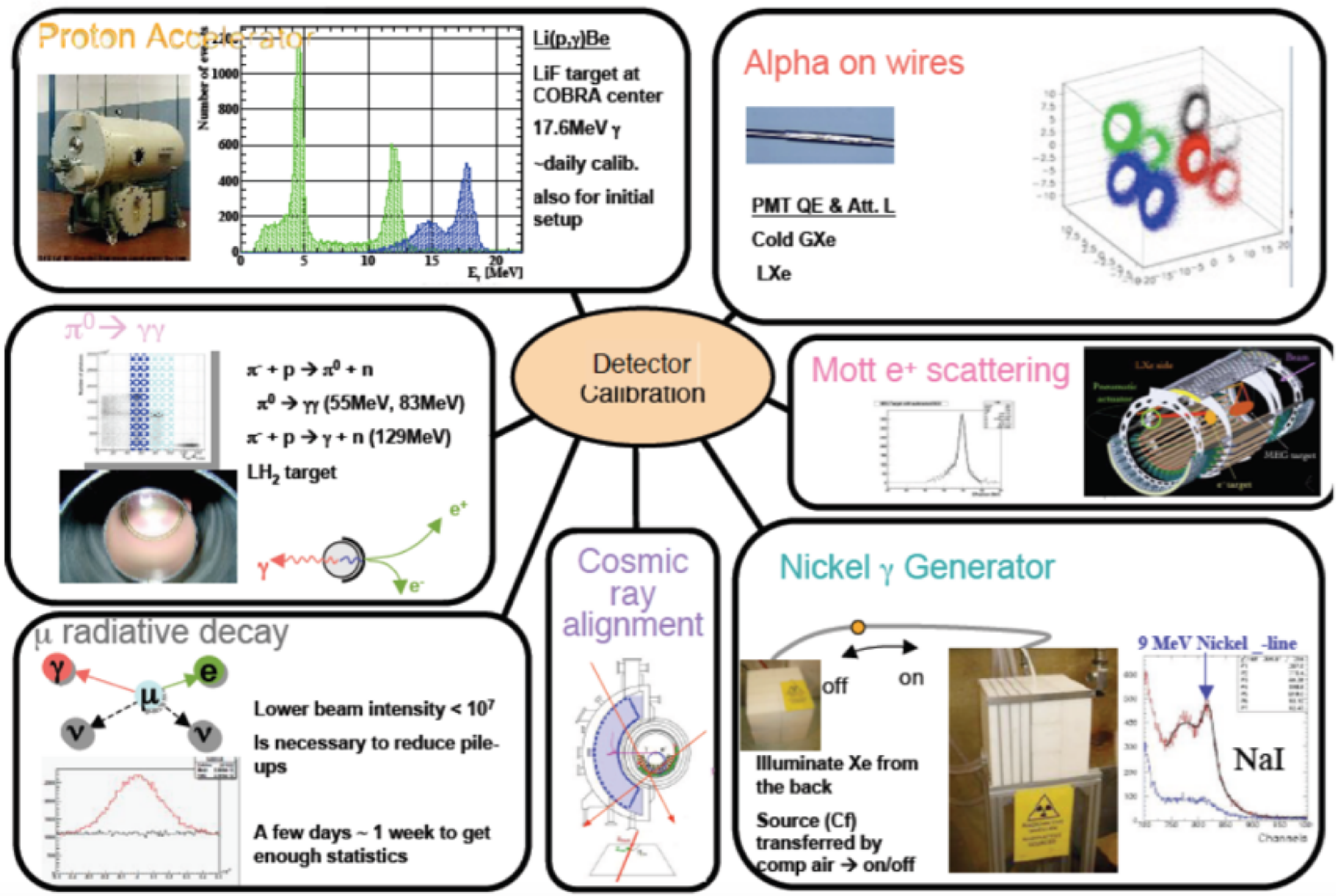
Also provides power and amplification for SiPM/MPPC

Had to face severe common-noise problems — now fixed —

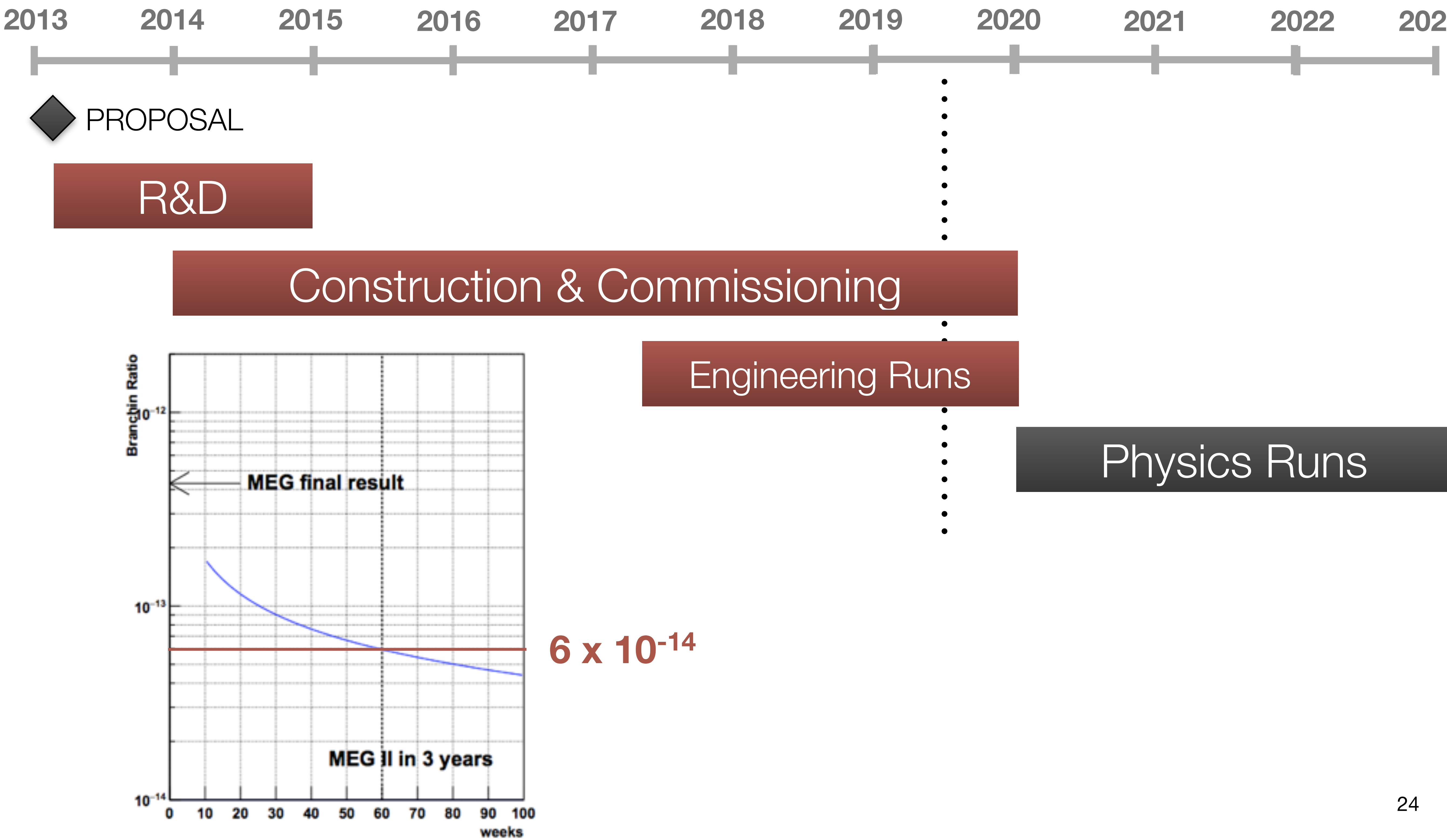
The design and test of the DAQ electronics is going to be finalized in the next few months, mass production will start immediately after



MEG-II Highlights - Calibrations



MEG-II schedule & sensitivity



Conclusions

- cLFV in muon decays is a **golden probe** for NP beyond the SM
- MEG currently gives the **best limits** on muon cLFV
- **MEG-II** will improve the sensitivity by a factor ~ 10
  - Calorimeter & Timing counter tested in 2017 and 2018
  - Drift chamber construction completed and first data collected on beam in 2018 — recommissioning in Spring 2019 allowed to bring the full detector to running conditions
- Engineering run in 2019 with the full detector under running conditions
- **First physics data expected in 2020**