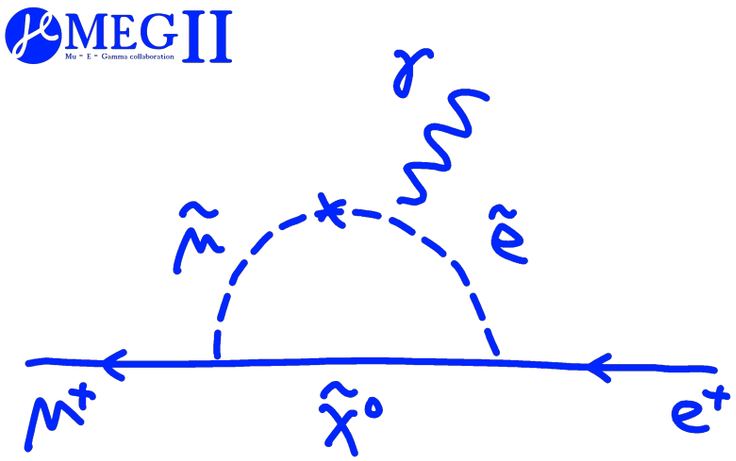
MEG final results and progress towards MEG II

Toshiyuki Iwamoto on behalf of the MEG II Collaboration
ICEPP, the University of Tokyo
27 September 2018
The 15th International Workshop on Tau Lepton Physics



JSPS Core-to-Core Program

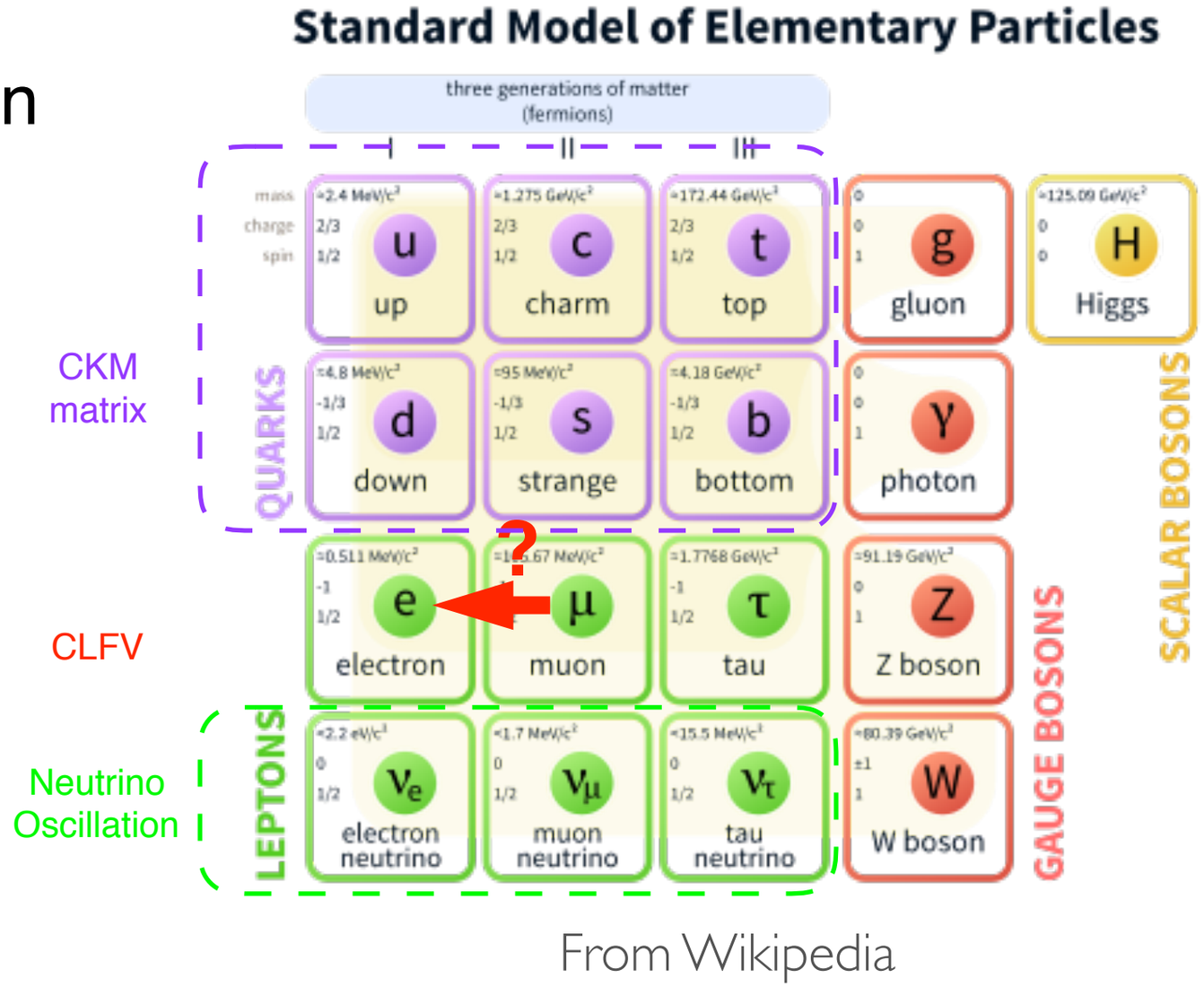
Introduction

- Flavor physics
  - Why do we have three generations in the SM?
- charged Lepton Flavor Violation
  - FV happens in quark, neutral lepton sector
  - Why not in charged lepton sector?
- μ→eγ
  - Long search history since the muon has been discovered.
  - Negative results contribute to the SM formation
  - In SM + neutrino oscillation, Br(μ→eγ)~10^{-50}
  - Many new physics scenarios predict large Br(μ→eγ)

CKM matrix

CLFV

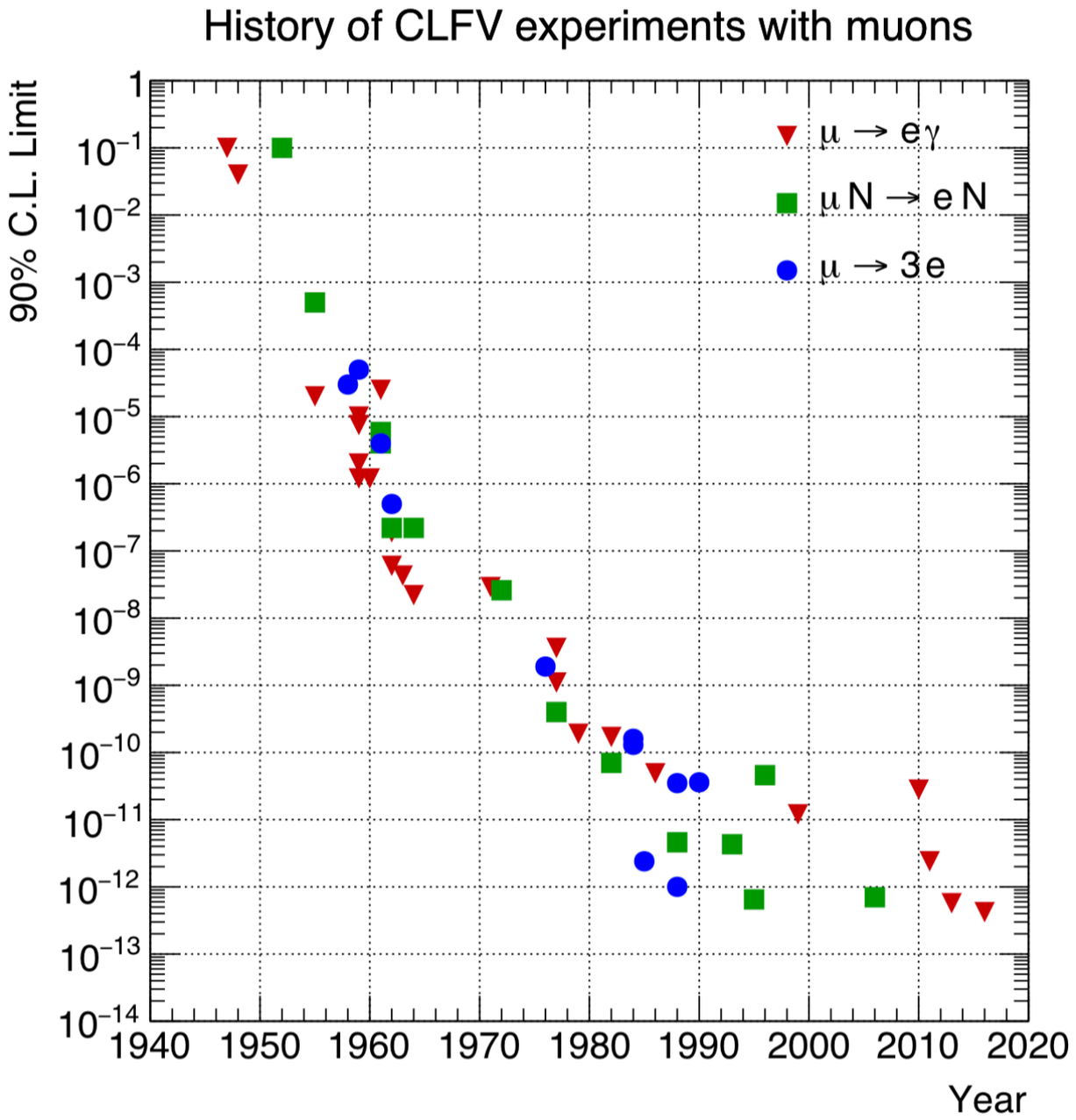
Neutrino Oscillation



From Wikipedia

MEG Experiment

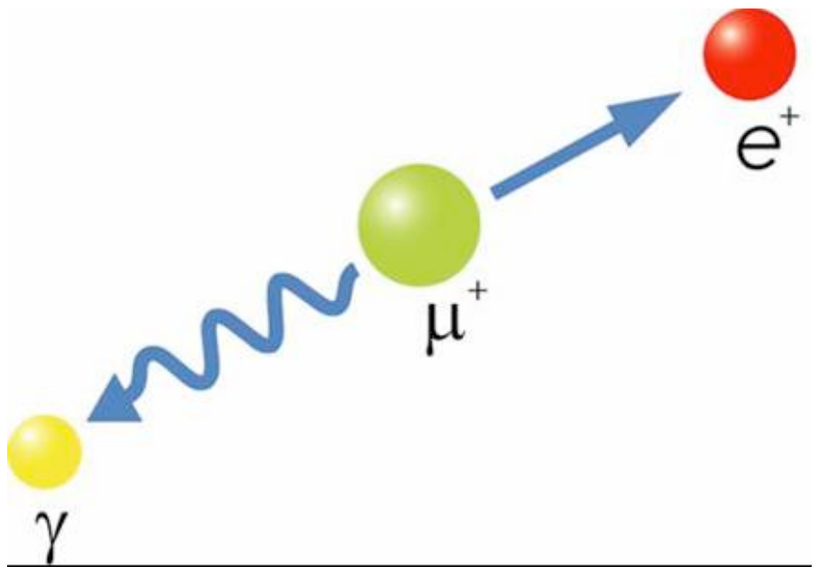
- MEG experiment
  - MEG was designed to search for such regions where new physics like SUSY-GUT, SUSY-seesaw predict
  - Real chance to discover new physics
  - Data taking done during 2009-2013
  - MEG final sensitivity : 5.3×10^{-13}
  - MEG final results : 4.2×10^{-13} @90%CL (Eur. Phys. J. C 76(8),434(2016))
- MEG II experiment
  - An order of magnitude better sensitivity with three years data taking than MEG
  - Target sensitivity : 6×10^{-14}
- μ-e conversion, μ→3e experiments, τ LFV results etc. will also come soon



Eur. Phys. J. C (2018)78:380

μ→eγ signal and background

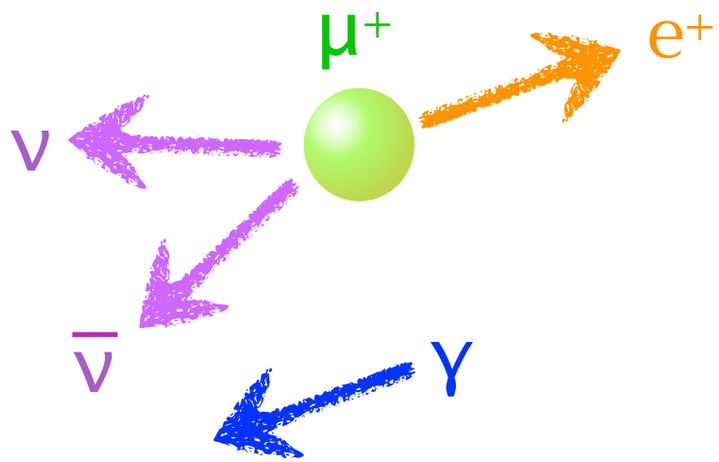
Signal



$E_r, E_e \simeq 52.8\text{MeV}$

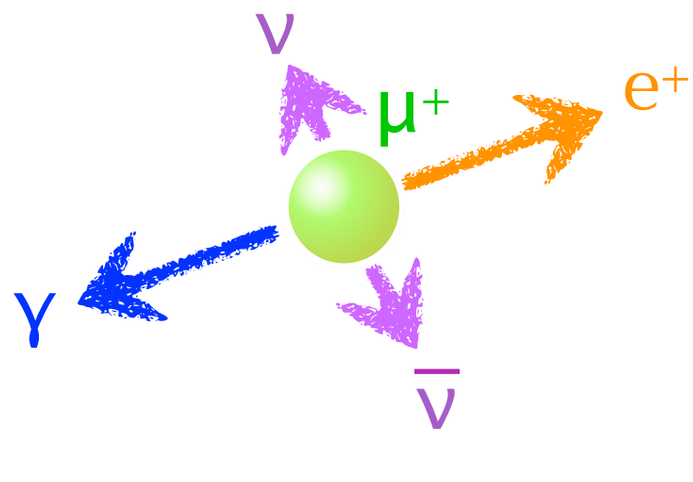
$\Theta_{er}=180^\circ,\ T_r=T_e$

Accidental Background



- Dominant BG
- Michel e^+ + random γ from RMD/Annihilation in flight (AIF)

Radiative Muon Decay (RMD) Background



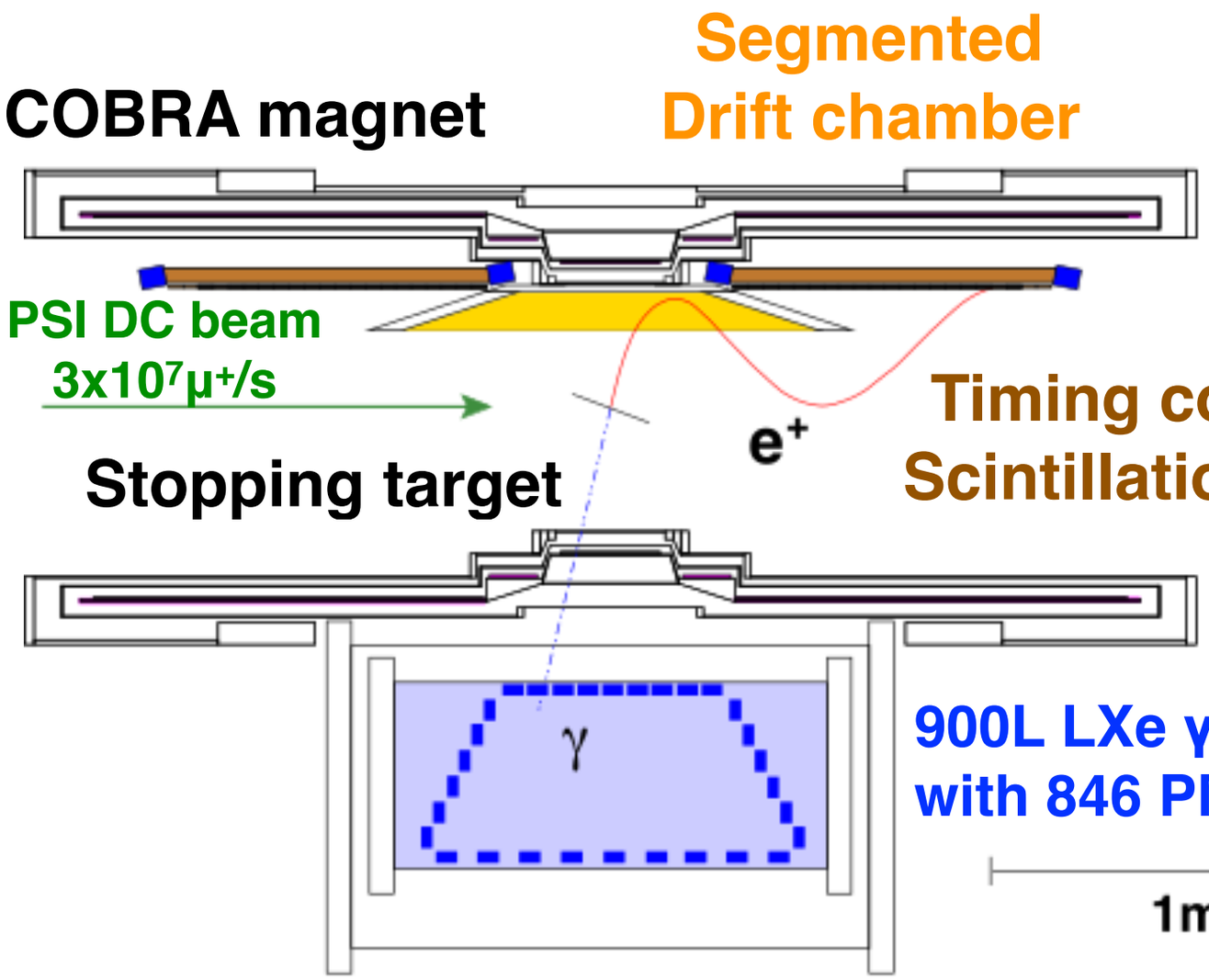
- e^+-γ timing coincident
- Good for timing calib.

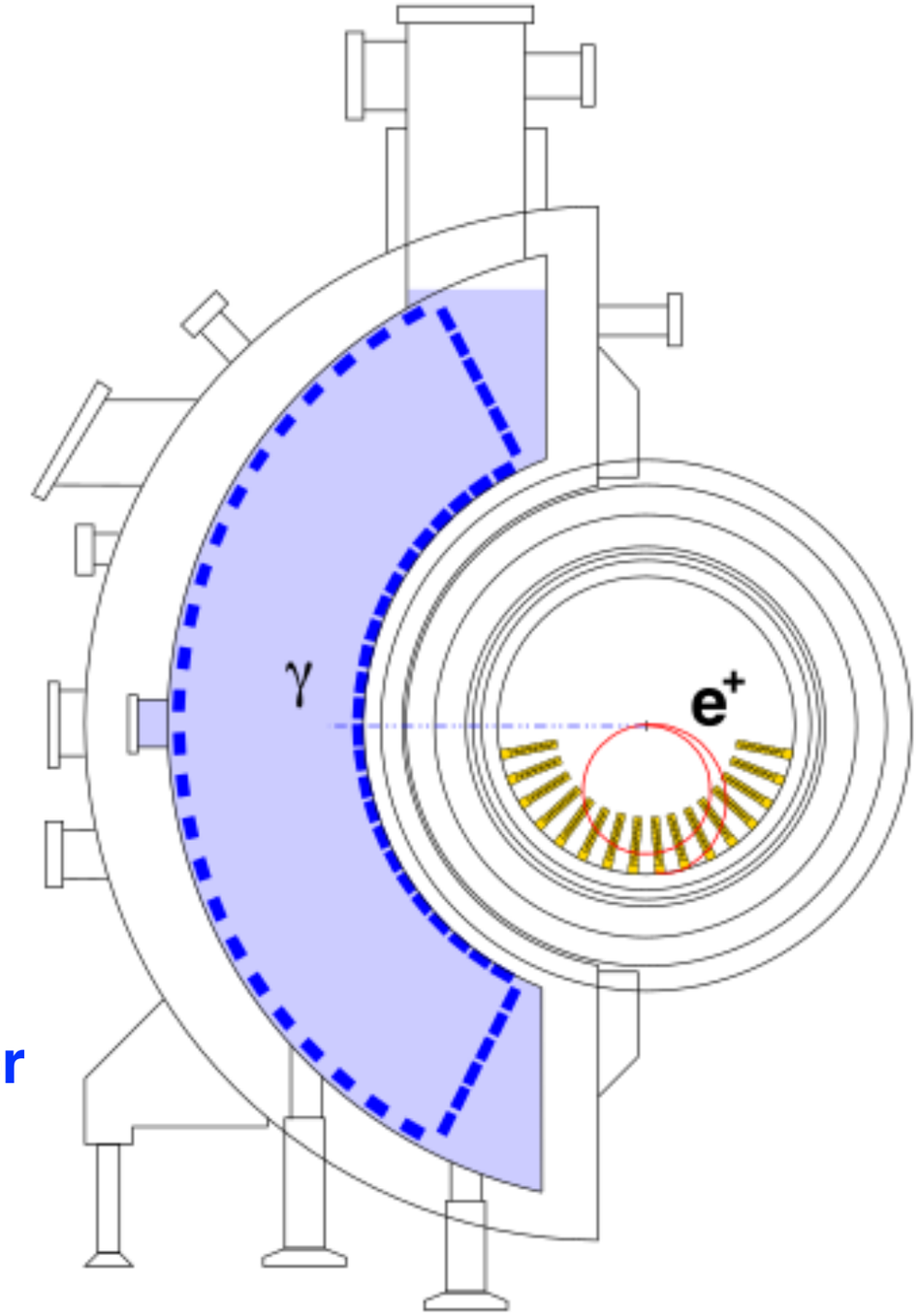
$$N_{acc} \propto R_\mu^2 \times \Delta E_\gamma^2 \times \Delta E_e \times \Delta \Theta_{e\gamma}^2 \times \Delta t_{e\gamma} \times T$$

- Lower instantaneous muon beam rate (DC muon beam)
- Better detector resolutions

MEG experiment

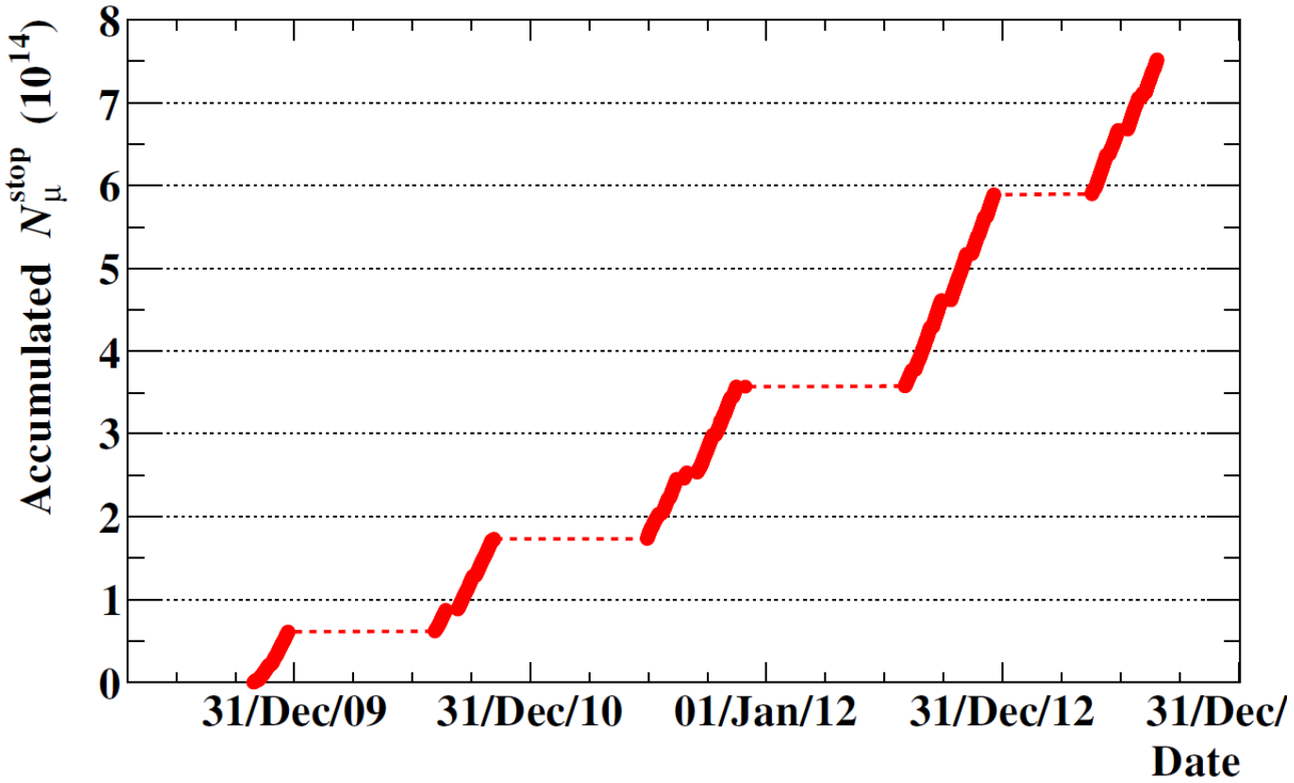
- Paul Scherrer Institute in Switzerland
- World most intense 590MeV proton accelerator (2.2mA)





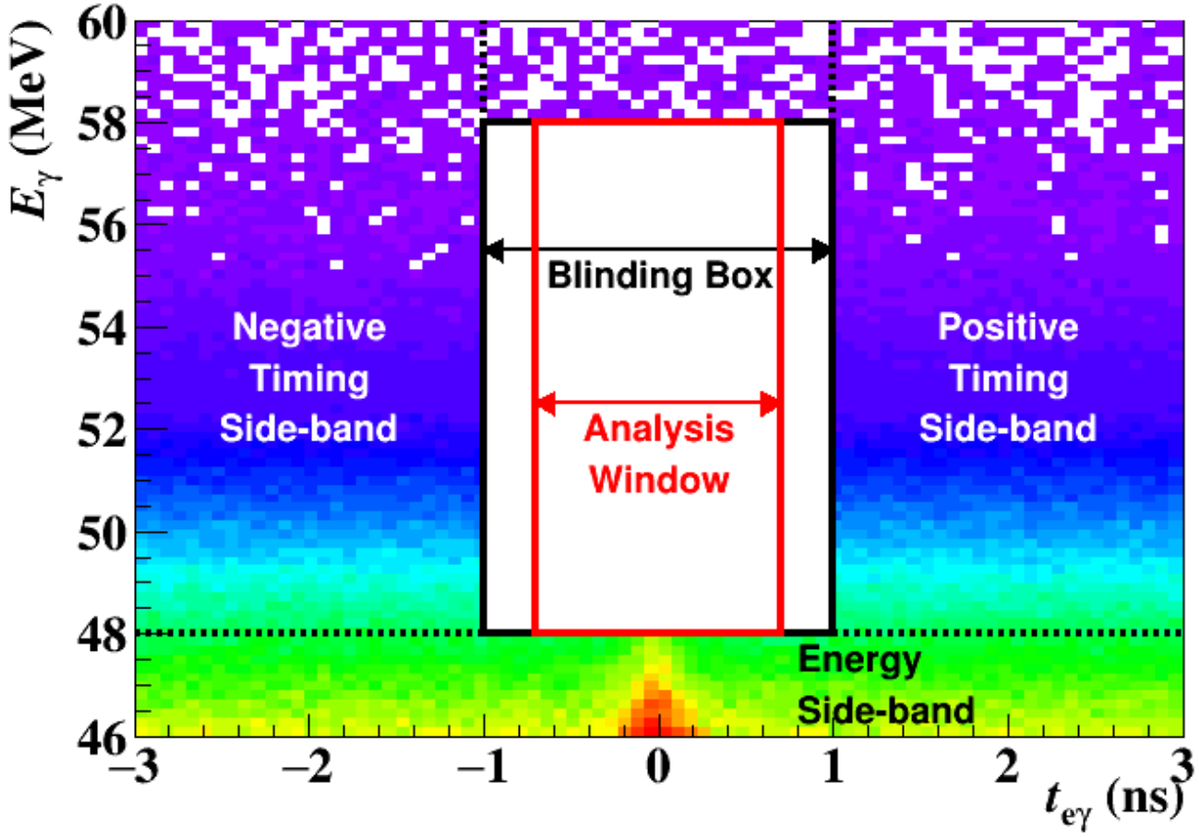
Final MEG dataset / Analysis

- Accumulated number of muons stopped on the target as a function of time



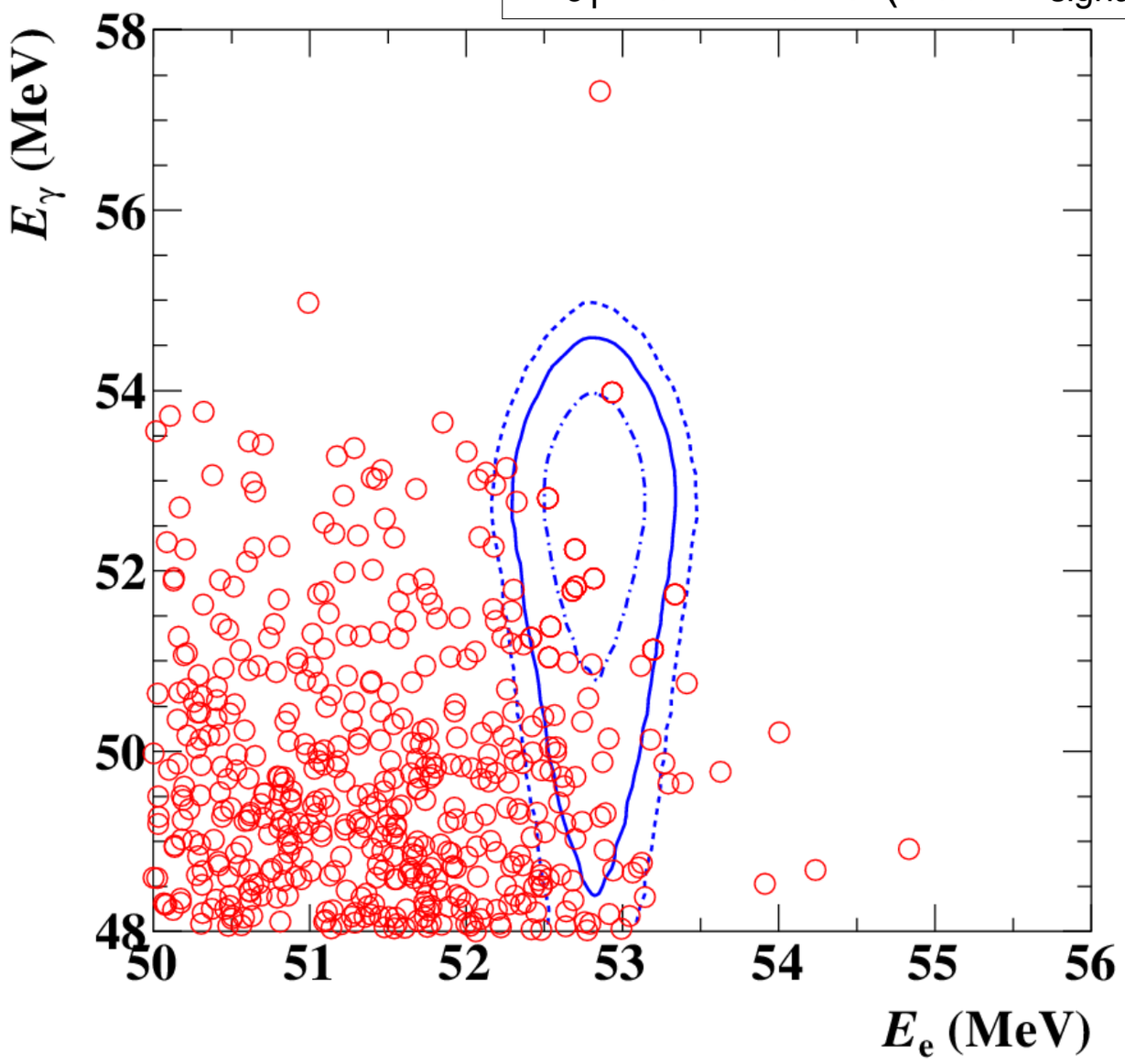
- Full dataset : 7.5×10^{14} μ^+ stopped on the target

- Blind analysis in (E_γ, $t_{e\gamma}$) plane
- Five observables
  $E_\gamma, E_e, t_{e\gamma}, \theta_{e\gamma}, \phi_{e\gamma}$
- Maximum likelihood analysis

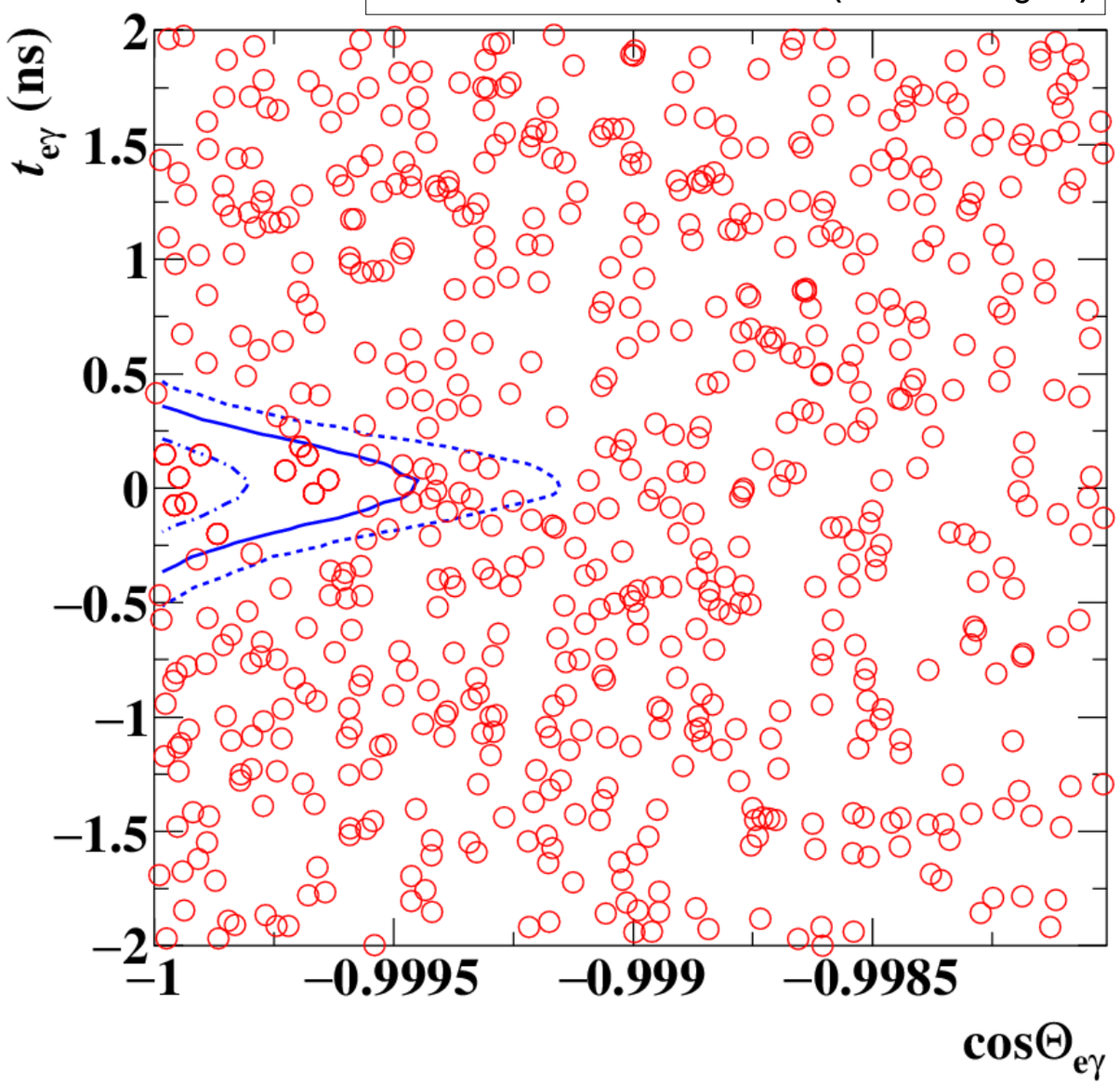


Event distribution

cosΘ<-0.99963 (90% ε_{signal})
$|t_{e\gamma}|$<0.2443ns (90% ε_{signal})



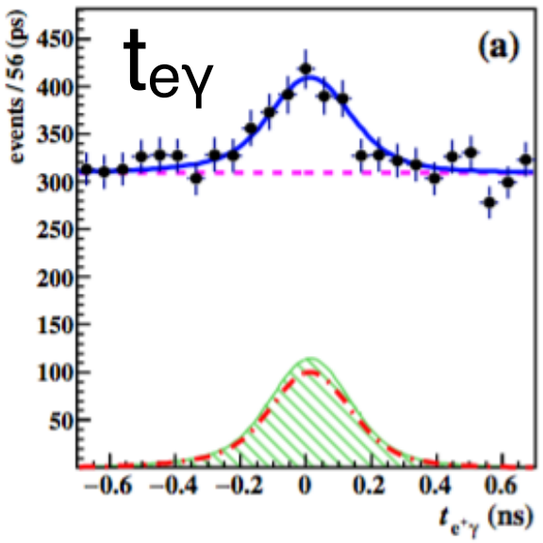
51<Eγ<55.5MeV (74% ε_{signal})
52.385<E_e<55MeV (90% ε_{signal})

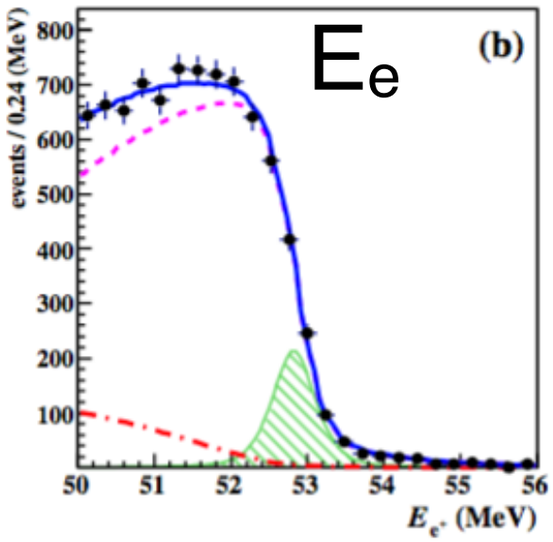


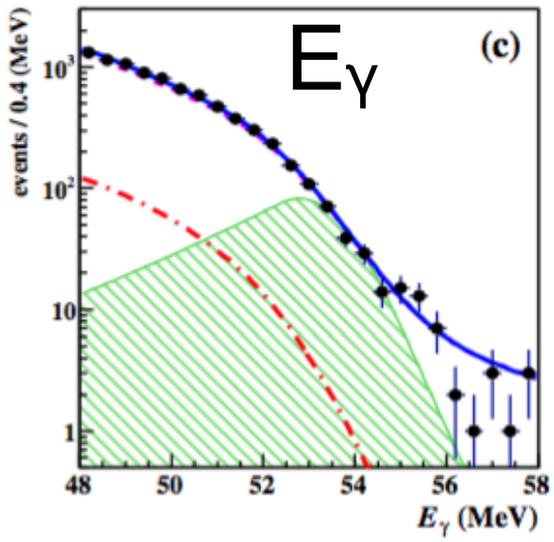
2009-2013 data

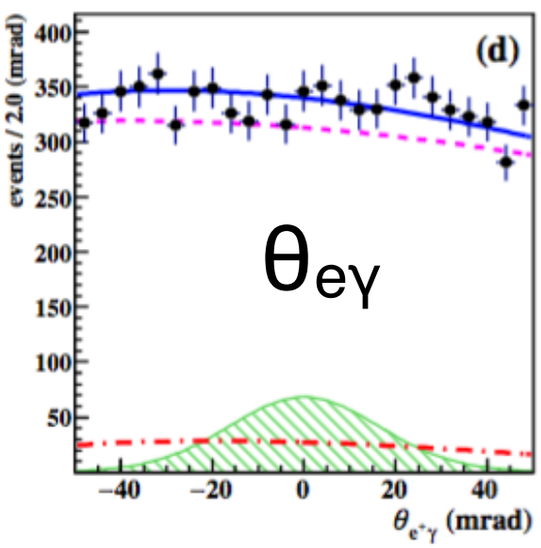
Signal PDF contour (1σ, 1.64σ, 2σ)

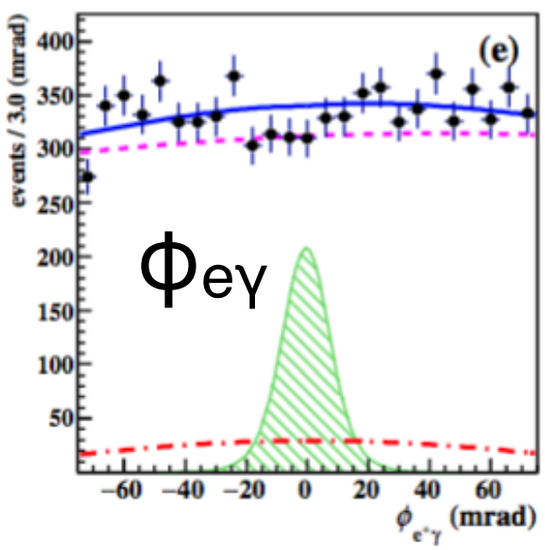
Likelihood fit result







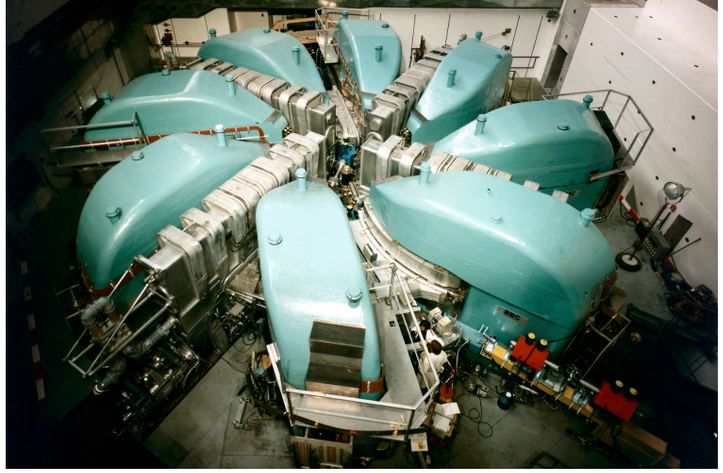




- All PDFs well consistent with data
- N_{ACC} = 7684 ± 103
- N_{RMD} = 663 ± 59
- Fit result : consistent with no signal
  - Signal PDF enhanced

- **Br($\mu^+ \to e^+\gamma$) < 4.2×10^{-13} @ 90% C.L.**

MEG II Experiment



PSI 590MeV proton cyclotron

Liquid Xenon γ Detector

Better uniformity w/ VUV-sensitive 12x12mm² SiPM

COBRA SC Magnet

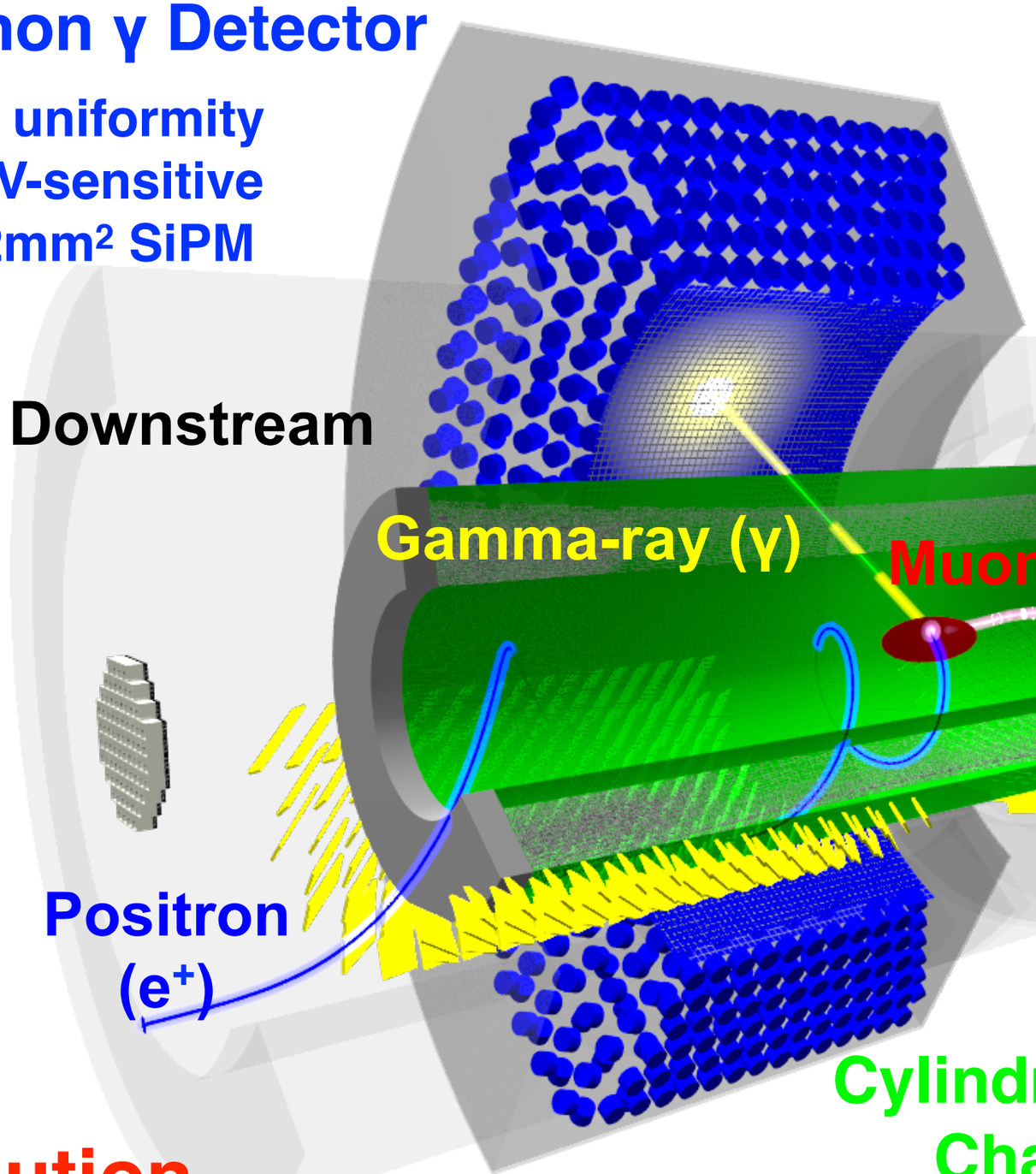
Upstream

Downstream

7x10⁷/s (x2.3)

Radiative Decay Counter

Further reduction of radiative BG



Pixelated Positron Timing Counter

30ps resolution w/ multiple hits

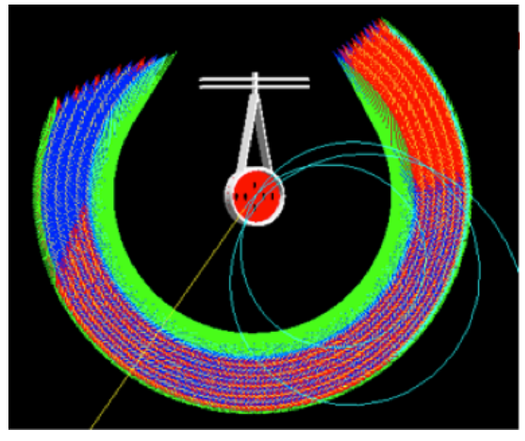
Cylindrical Drift Chamber

Single volume small stereo cells more hits

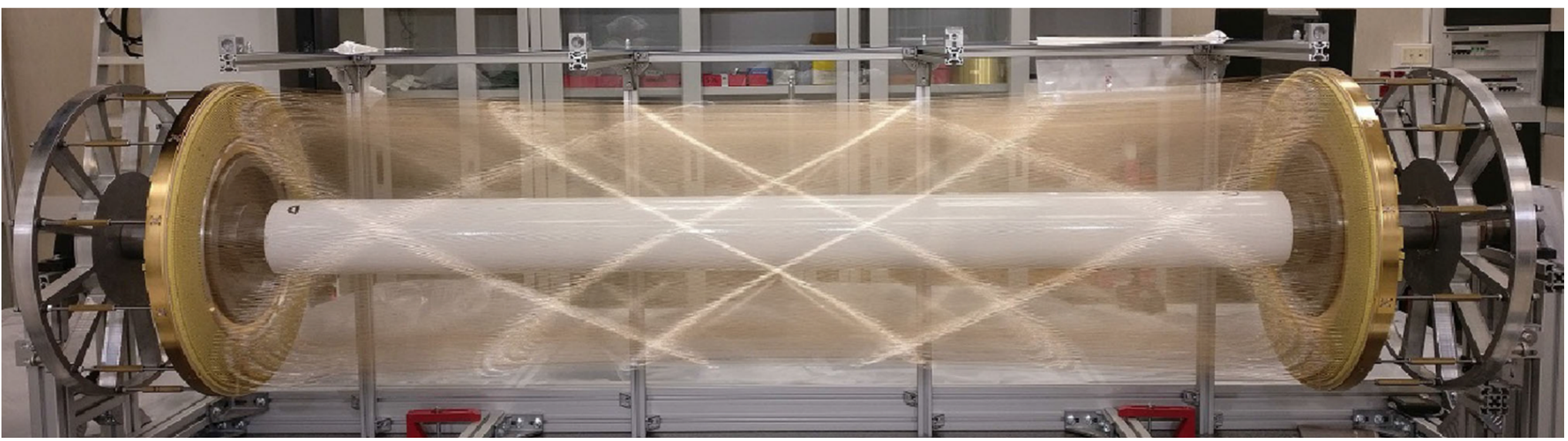
x2 resolution everywhere

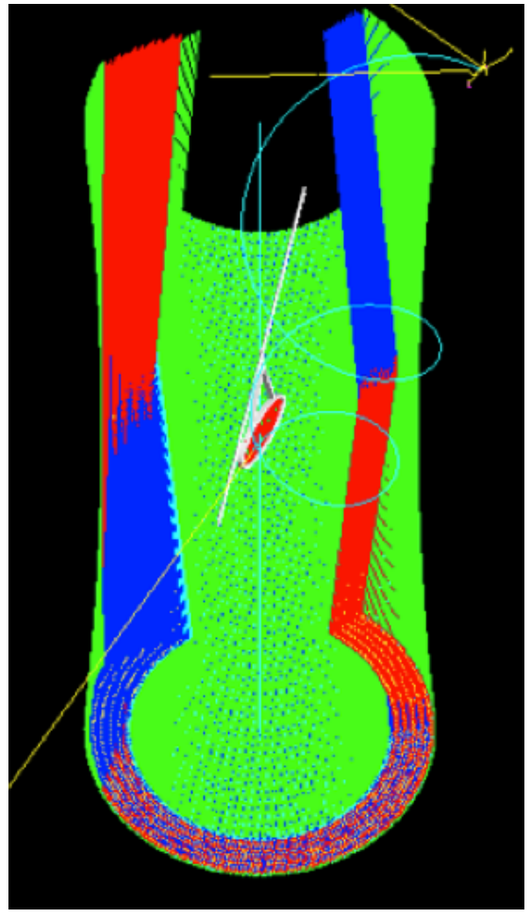
Cylindrical Drift Chamber

- Tracking 52.8MeV e^+ to reconstruct vertex, angle, and momentum
- Single volume wire drift chamber with 1280 anode wires
- Higher granularity, increased number of hits per track



MEG DCH	MEG II CDCH
16 modules	single volume
288 drift cells	1280 drift cells
40-80cm	2m long, stereo angle
$He:C_2H_6=50:50$	$He:iC_4H_{10}=85:15$

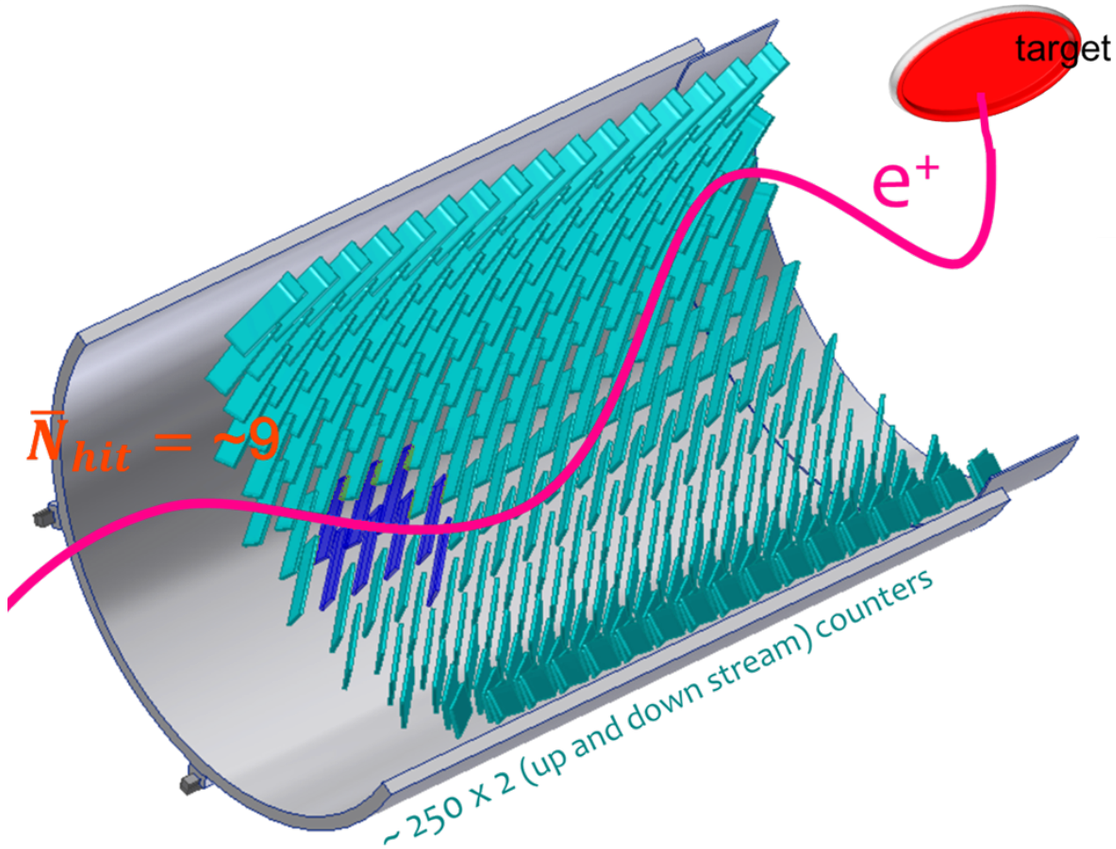


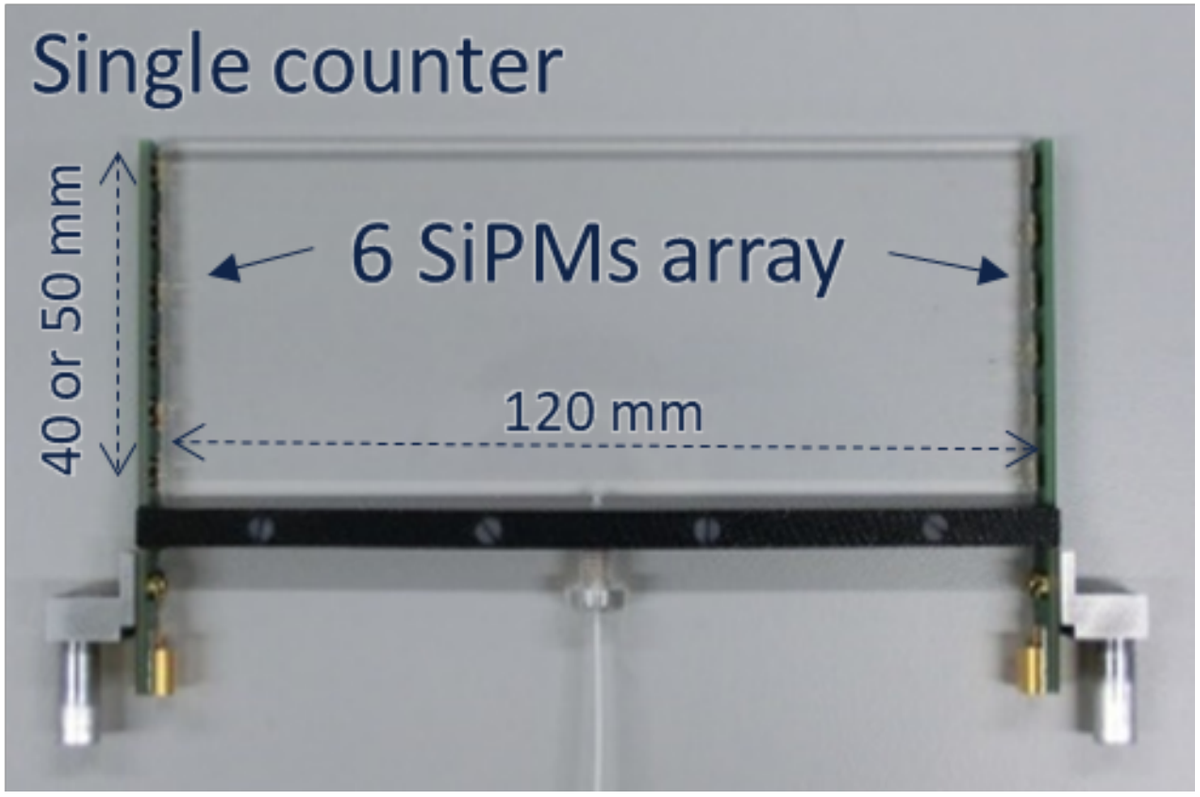


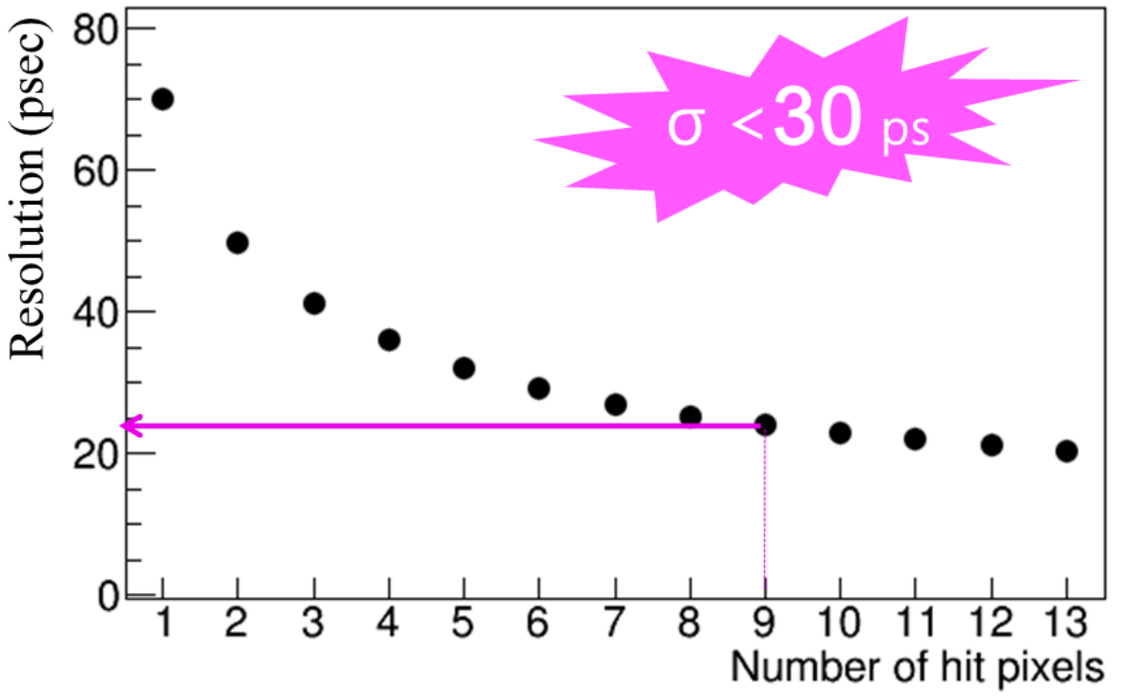
MEG II timing counter

- Time measurement of 52.8MeV e^+

MEG TC	MEG II TC
15 scintillating bars x 2	256 scintillator plates x 2
4x4x80 cm^3	12x(4or5)x0.5 cm^3
Readout by PMTs	Readout by SiPM
Single bar hit	Multiple counter hits

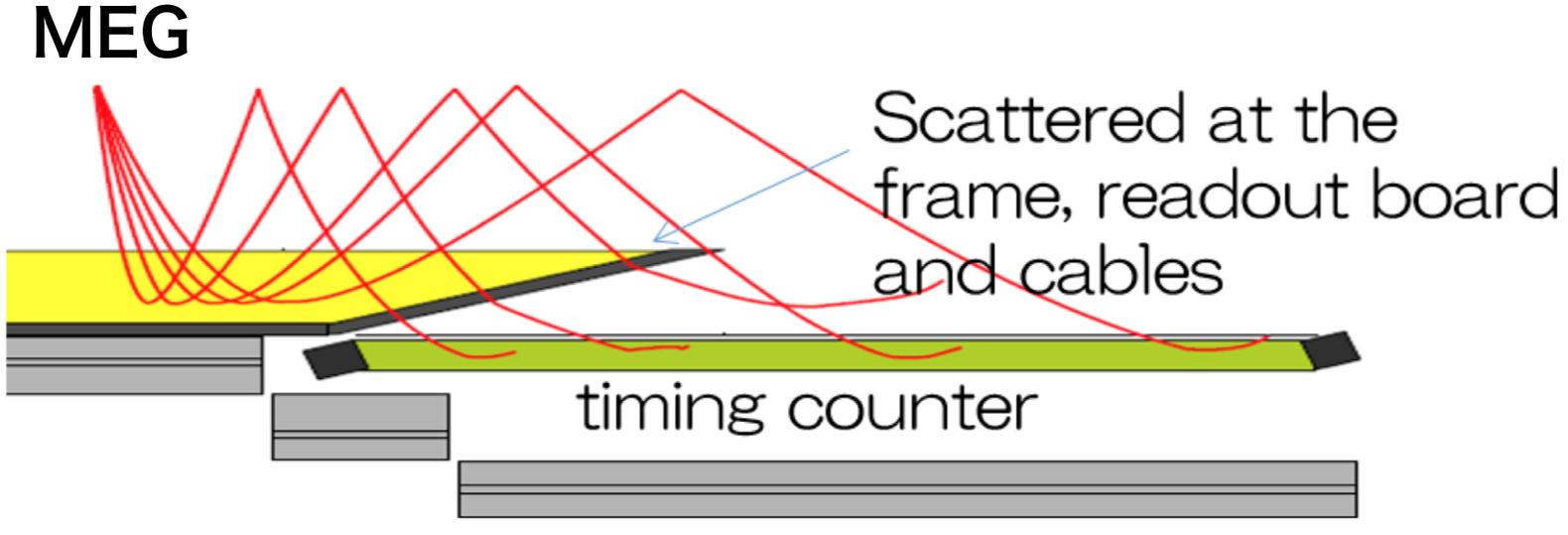


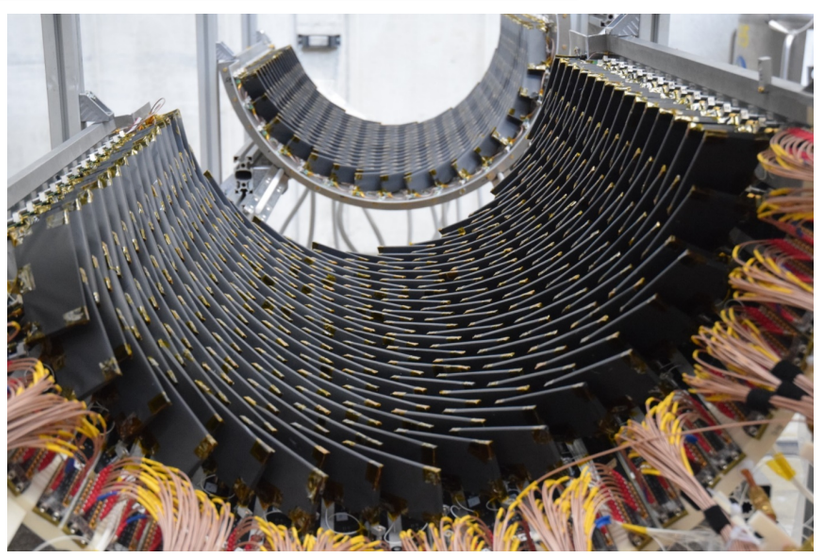




Positron spectrometer

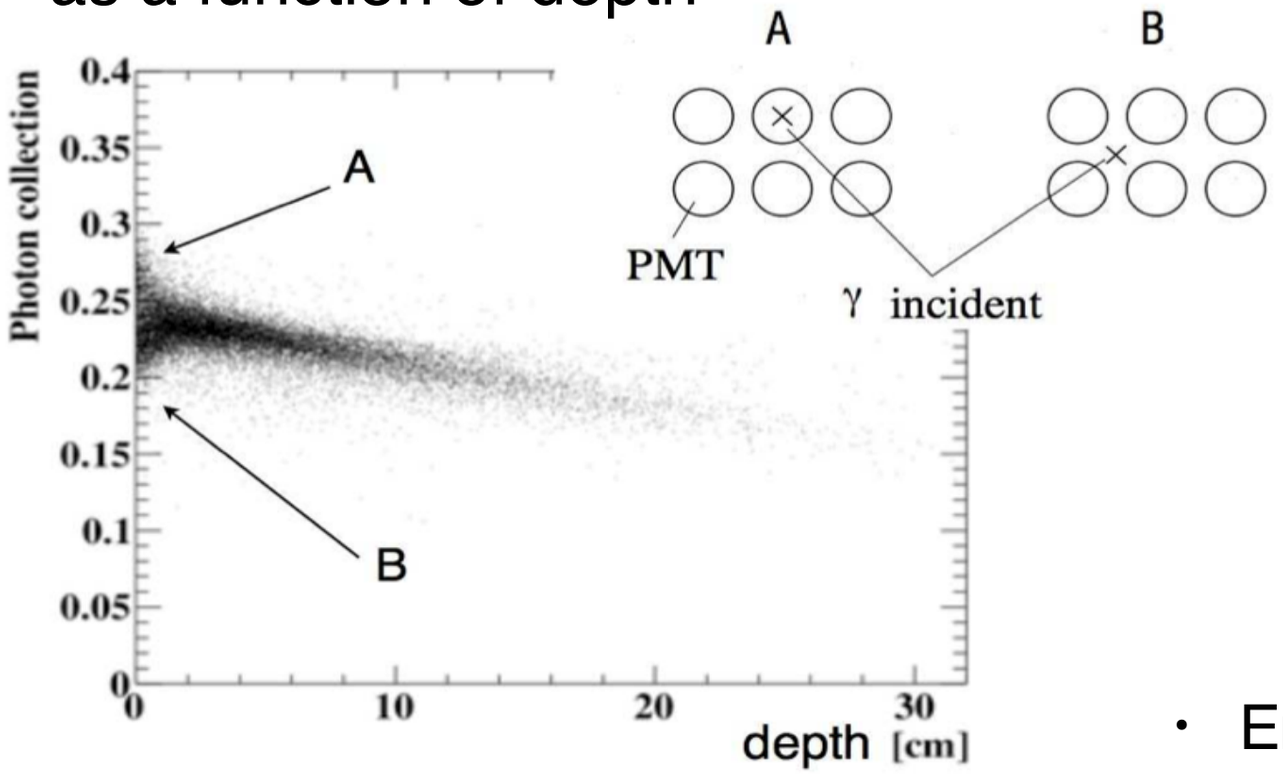
- CDCH less material
- High transparency towards TC
- Higher positron detection efficiency

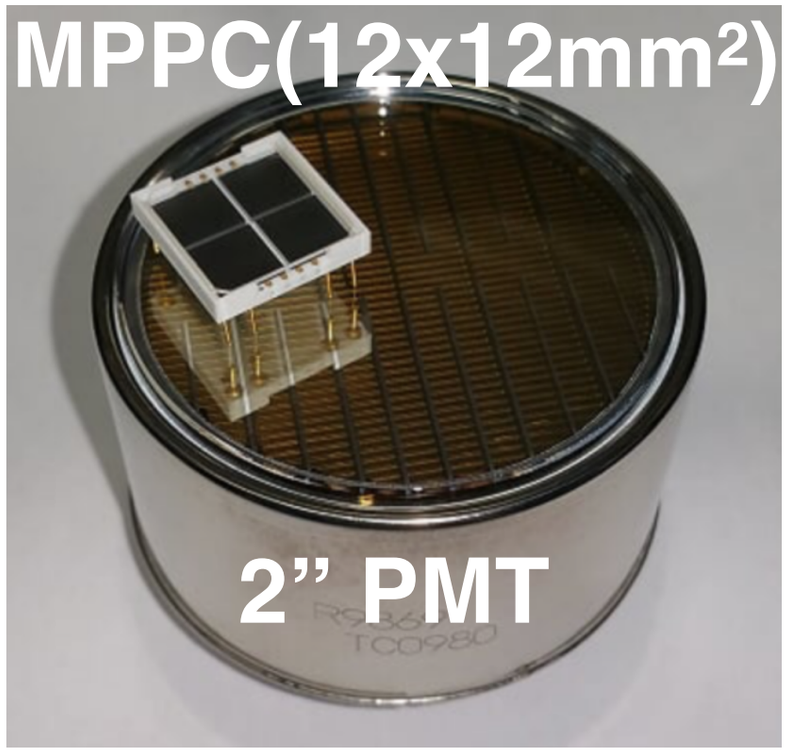




MEG II liquid xenon γ detector

of photons collected by PMTs
as a function of depth



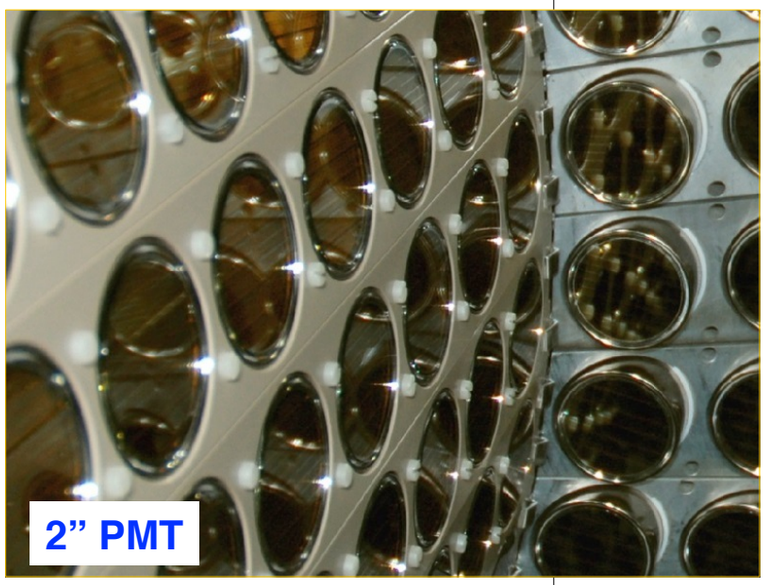


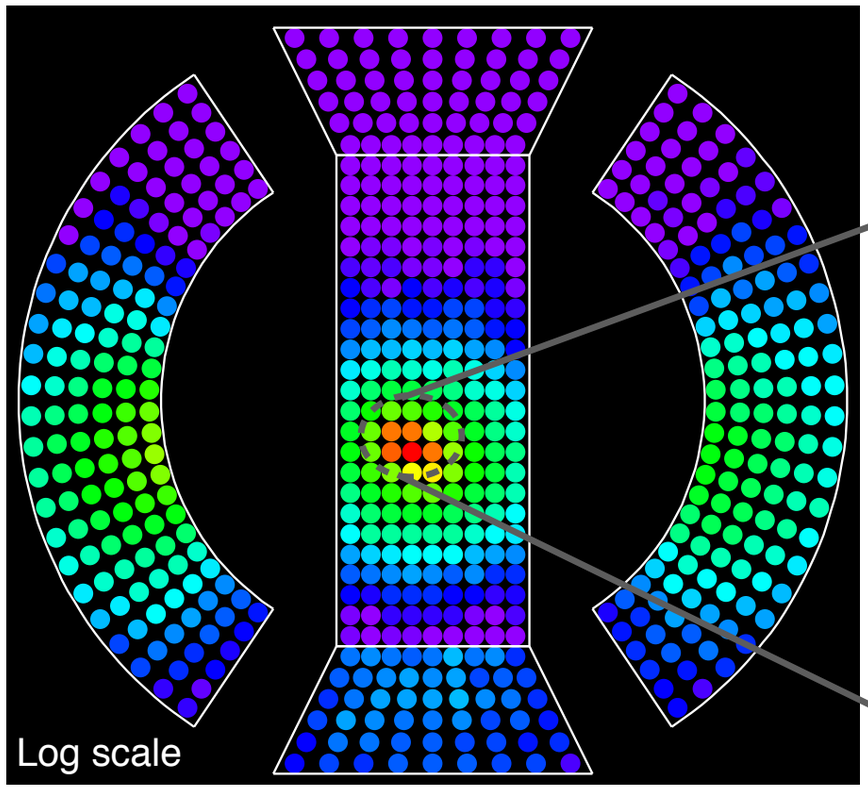
- Energy, position, time measurement of 52.8MeV γ from μ→eγ decay

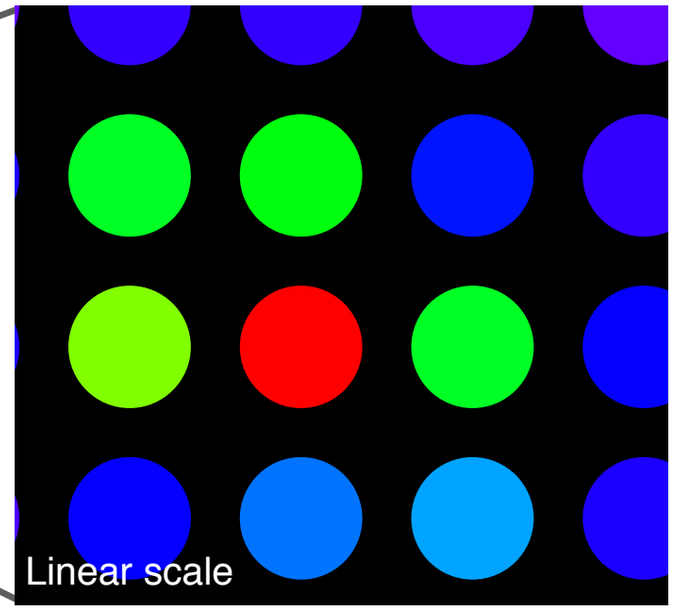
MEG LXe	MEG II LXe
900L LXe	900L LXe
216 2”PMTs (γ entrance)	4092 12x12mm² MPPCs
630 PMTs (other faces)	668 PMTs

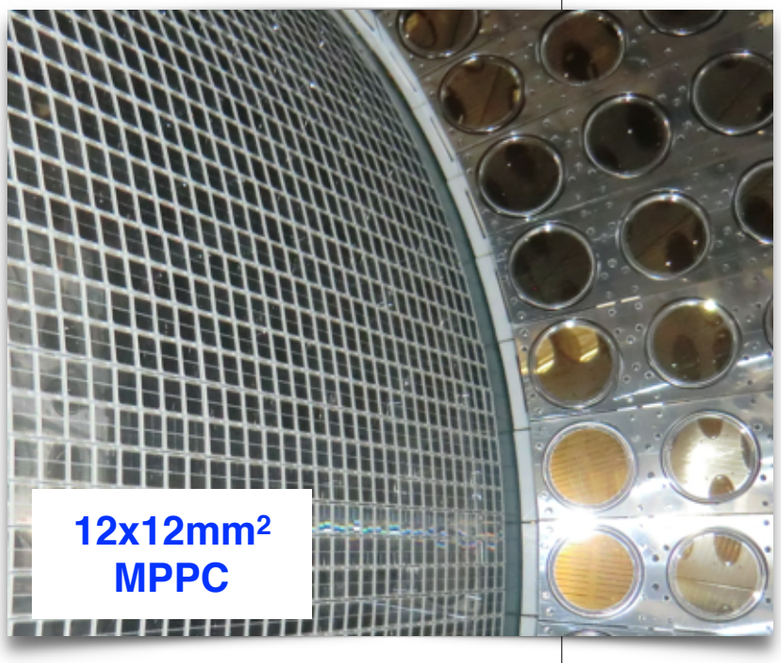
- Non uniform response for shallow events
- Replace inner PMTs with MPPCs
- Better granularity, better uniformity
  →Better energy, position resolution

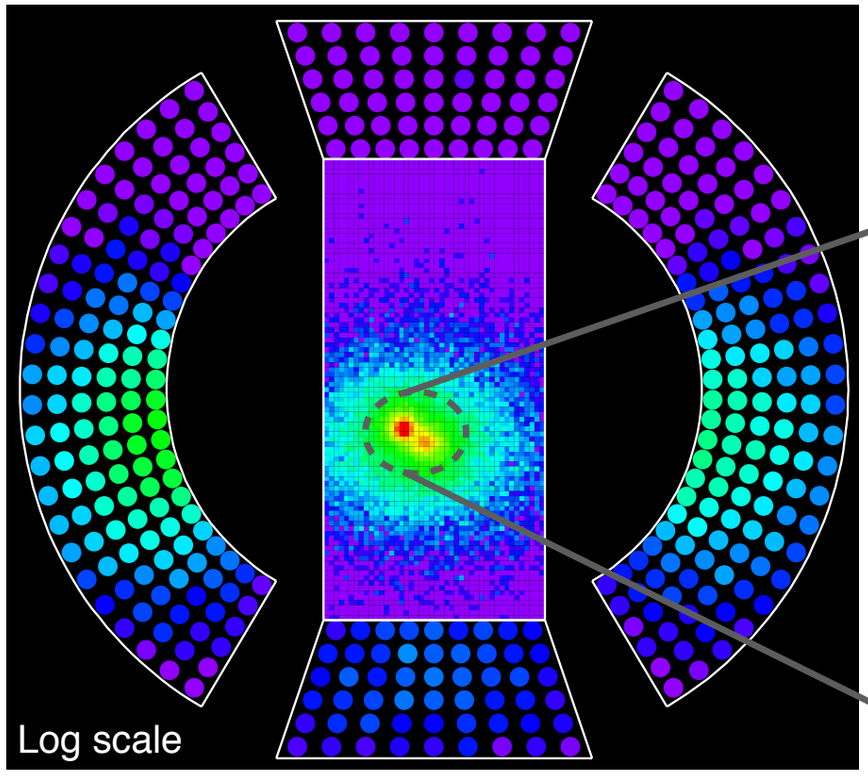
Liquid xenon γ detector

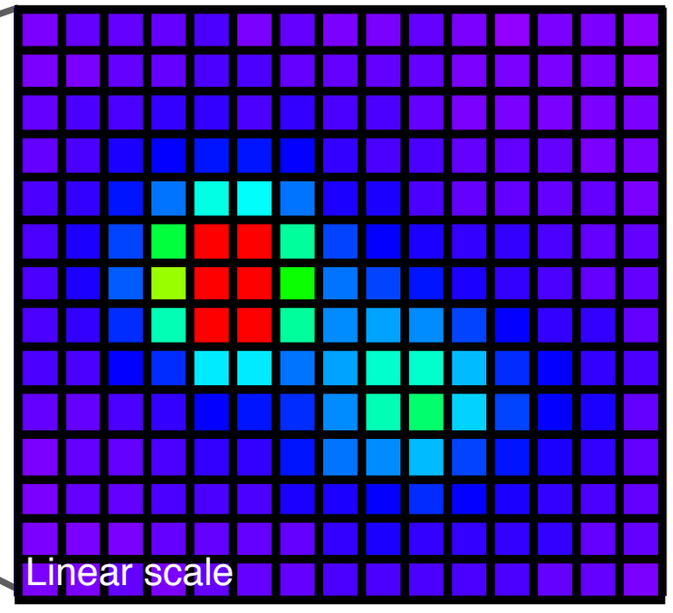








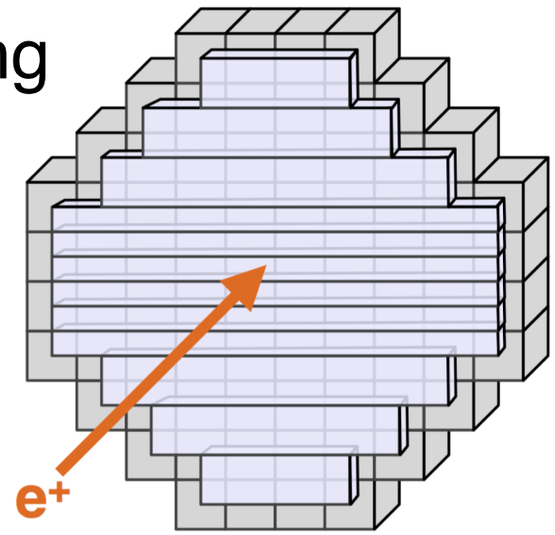




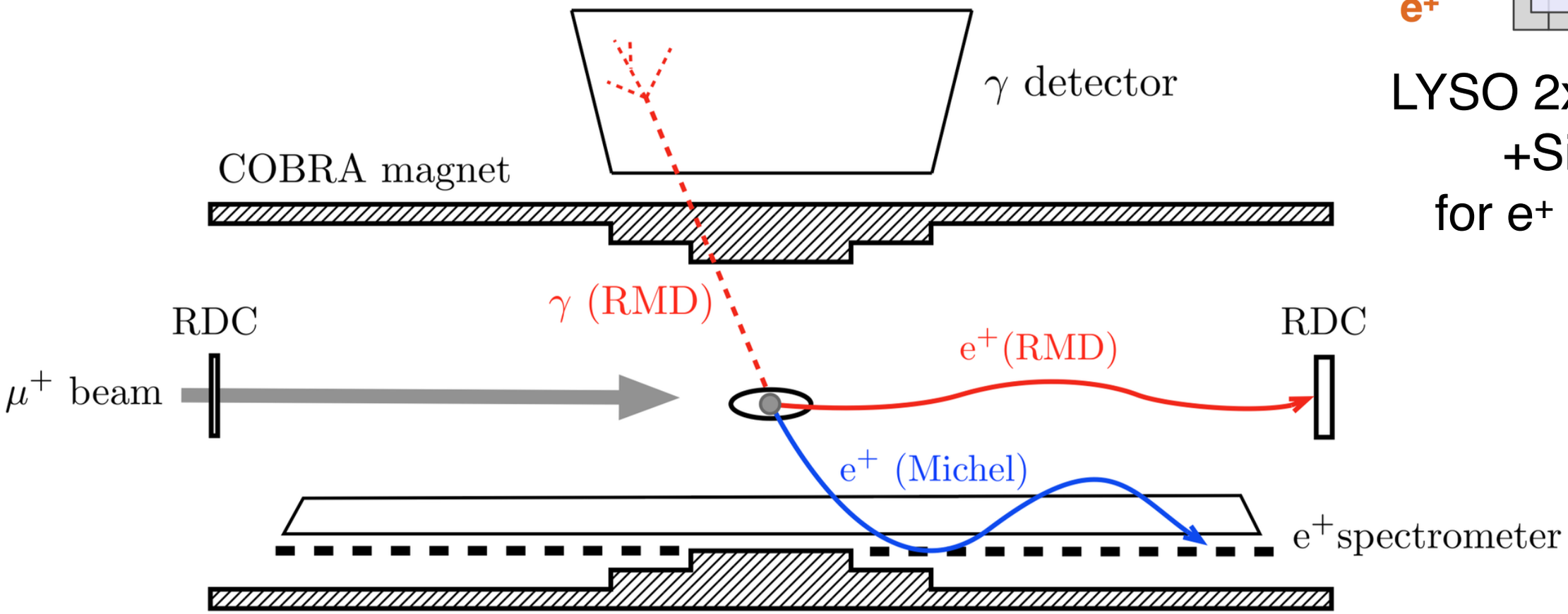
Radiative Decay Counter

- New device for MEG II
- To tag high energy γ background from radiative muon decay
  by detecting low momentum e^+
- Downstream detector ready, upstream detector under development

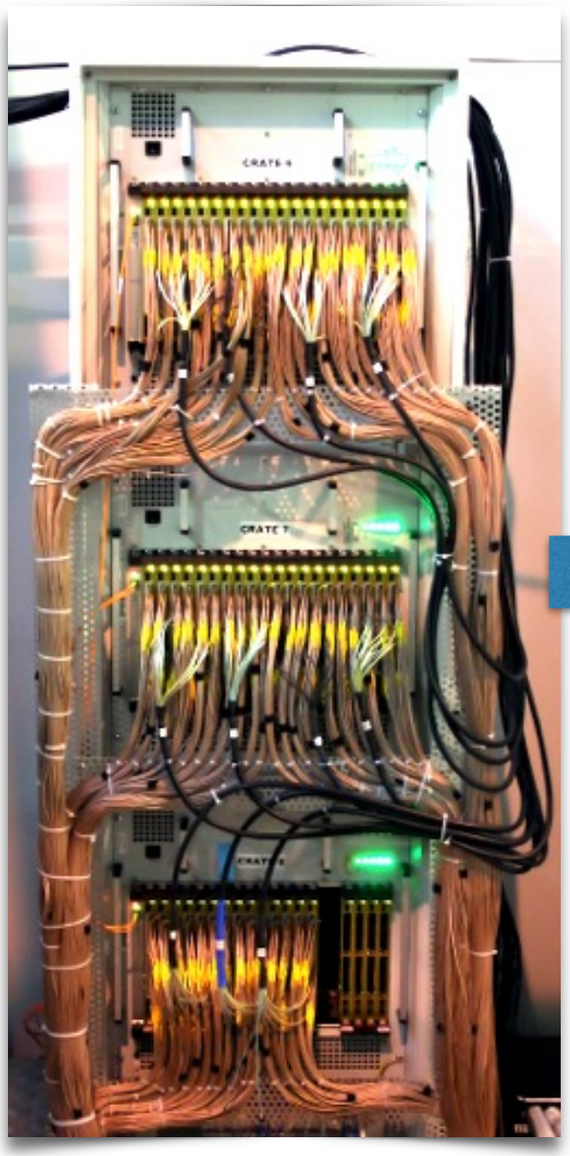
PS+SiPM
for e^+ timing

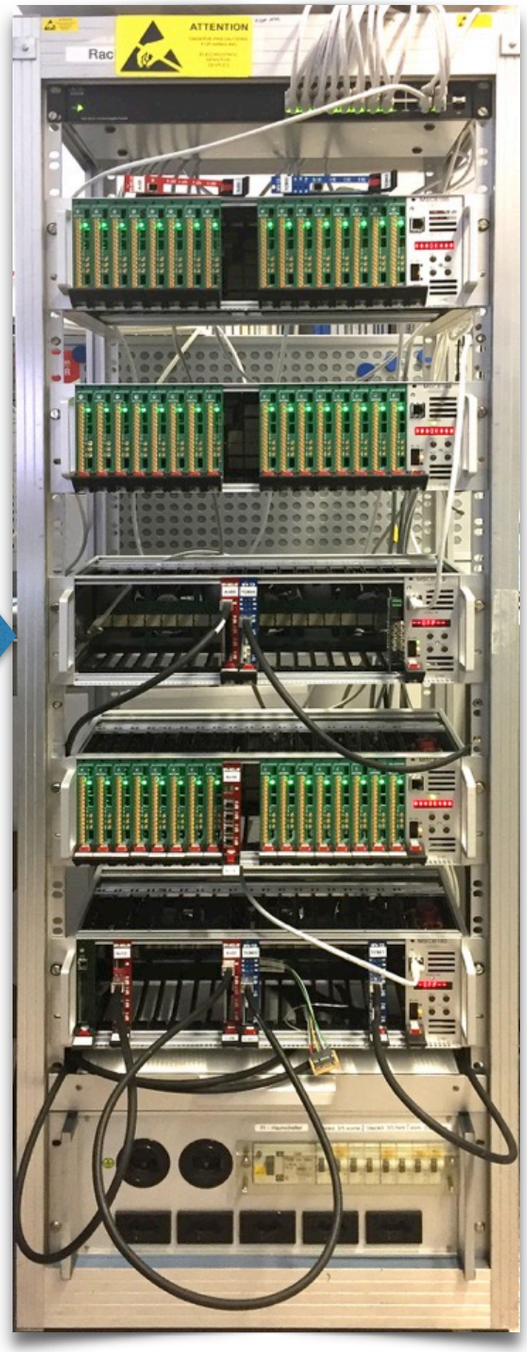


LYSO 2x2x2 cm^3
+SiPM
for e^+ energy



Readout Electronics

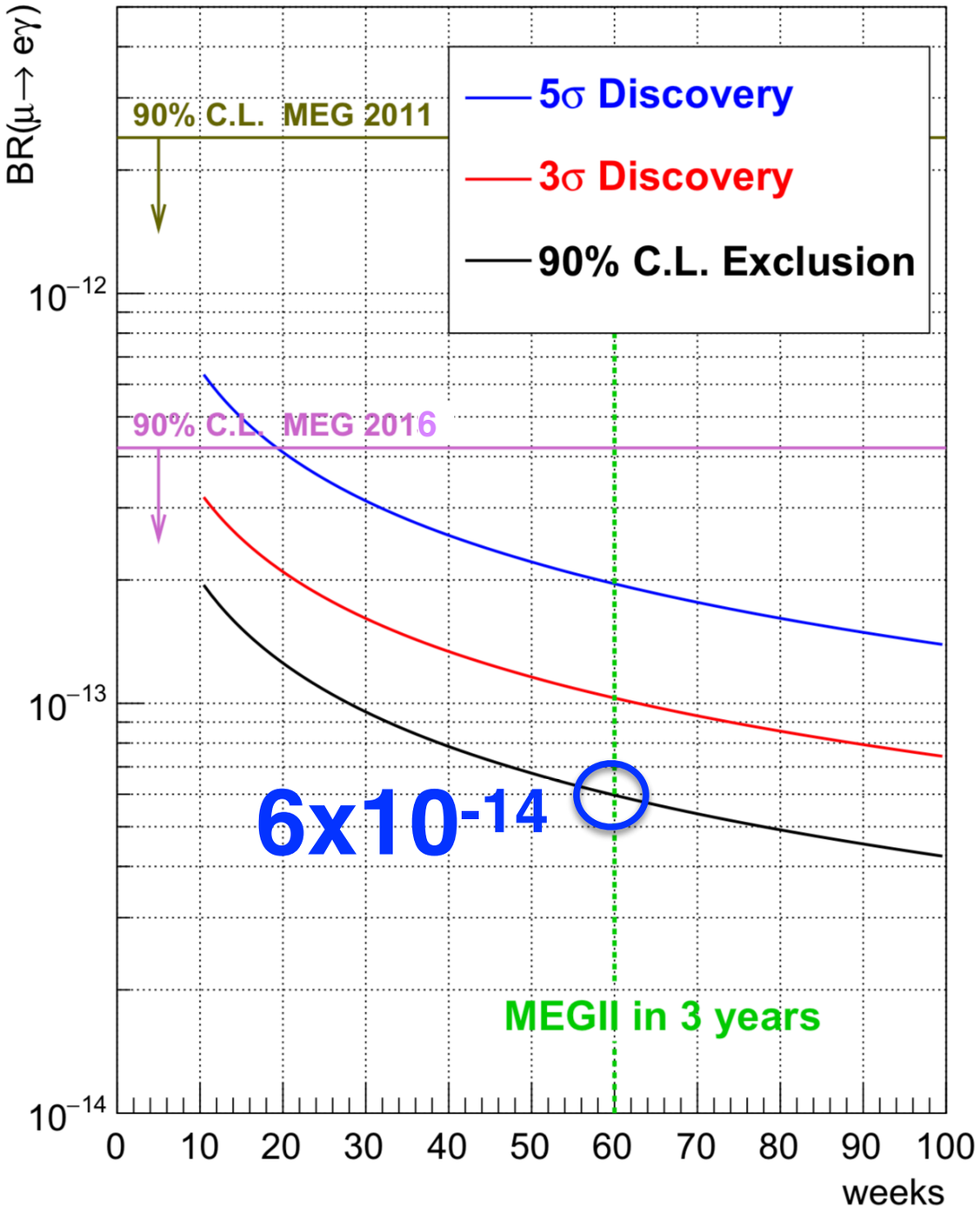




- Waveform data crucial for high rate environment
- Number of channels increased
  - For finer granularity
  - More compact boards necessary
  - Waveform digitizer(DRS4) , simple trigger, amplifier and bias voltage supply (~200V) are integrated in a board, suitable for SiPM
  - Called WaveDREAM, developed by PSI
- Online trigger important to manage high event rate and background suppression.
  - FPGA based trigger system prepared

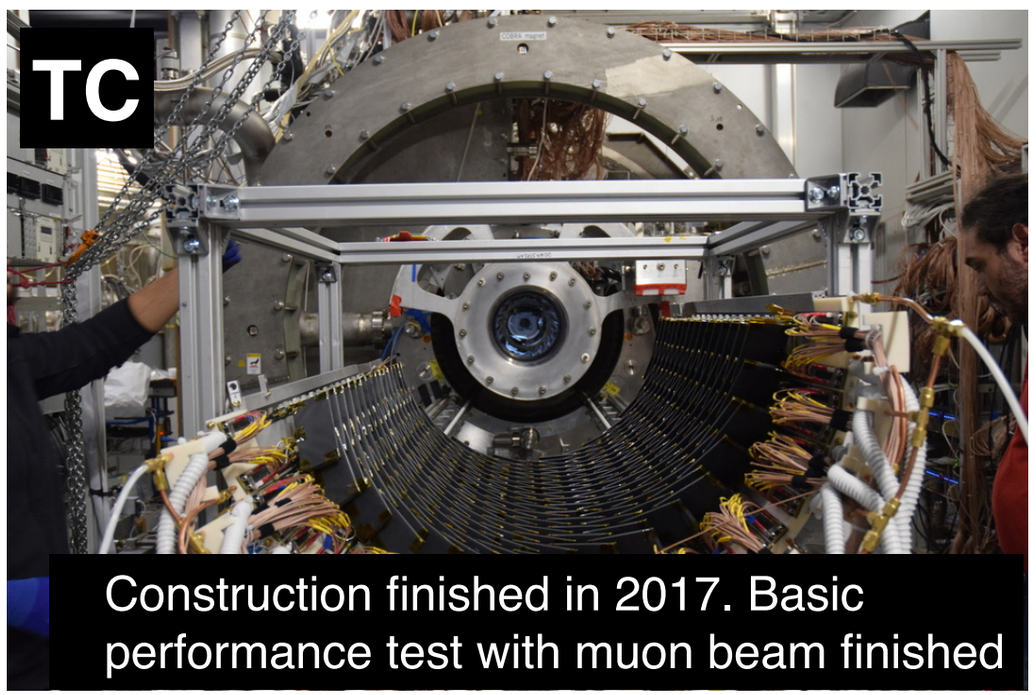
Sensitivity

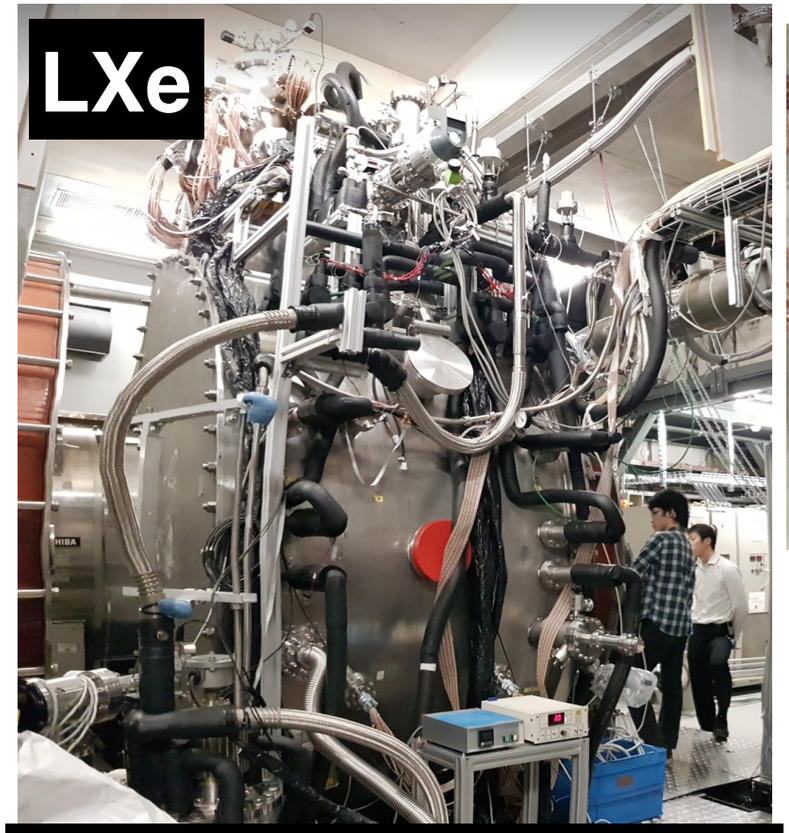
	MEG	MEG II
E_{e+} (keV)	380	130
θ_{e+} (mrad)	9.4	5.3
ϕ_{e+} (mrad)	8.7	3.7
z_{e+}/y_{e+} (mm) core	2.4/1.2	1.6/0.7
E_γ(%) (w>2cm/w<2cm)	1.7/2.4	1.0/1.1
u_γ, v_γ, w_γ (mm)	5/5/6	2.6/2.2/5
$t_{e\gamma}$ (ps)	122	84
Efficiency (%)		
Trigger	99	99
γ	63	69
e_+ (tracking x matching)	30	70

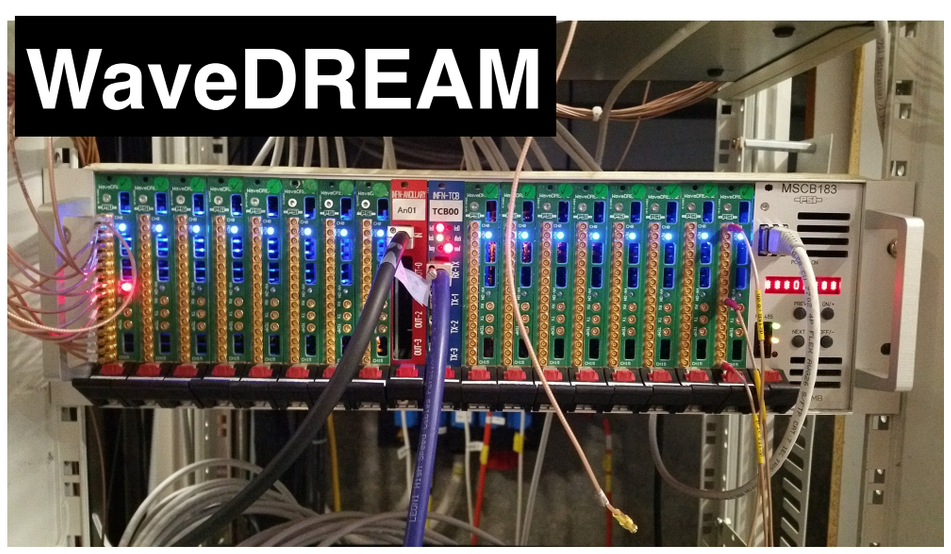


- Data for a few months exceed the current limit, and reach 6×10^{-14} in three years

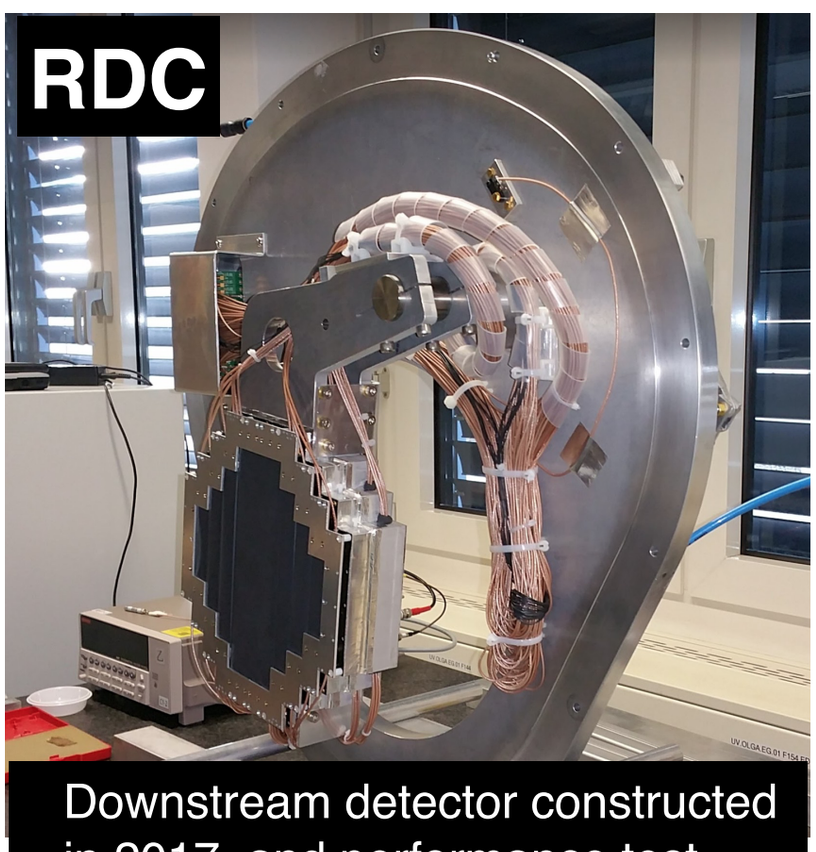
Current status







Prototype WaveDREAM tests with 6 crates (~1500ch.), and mass production next year



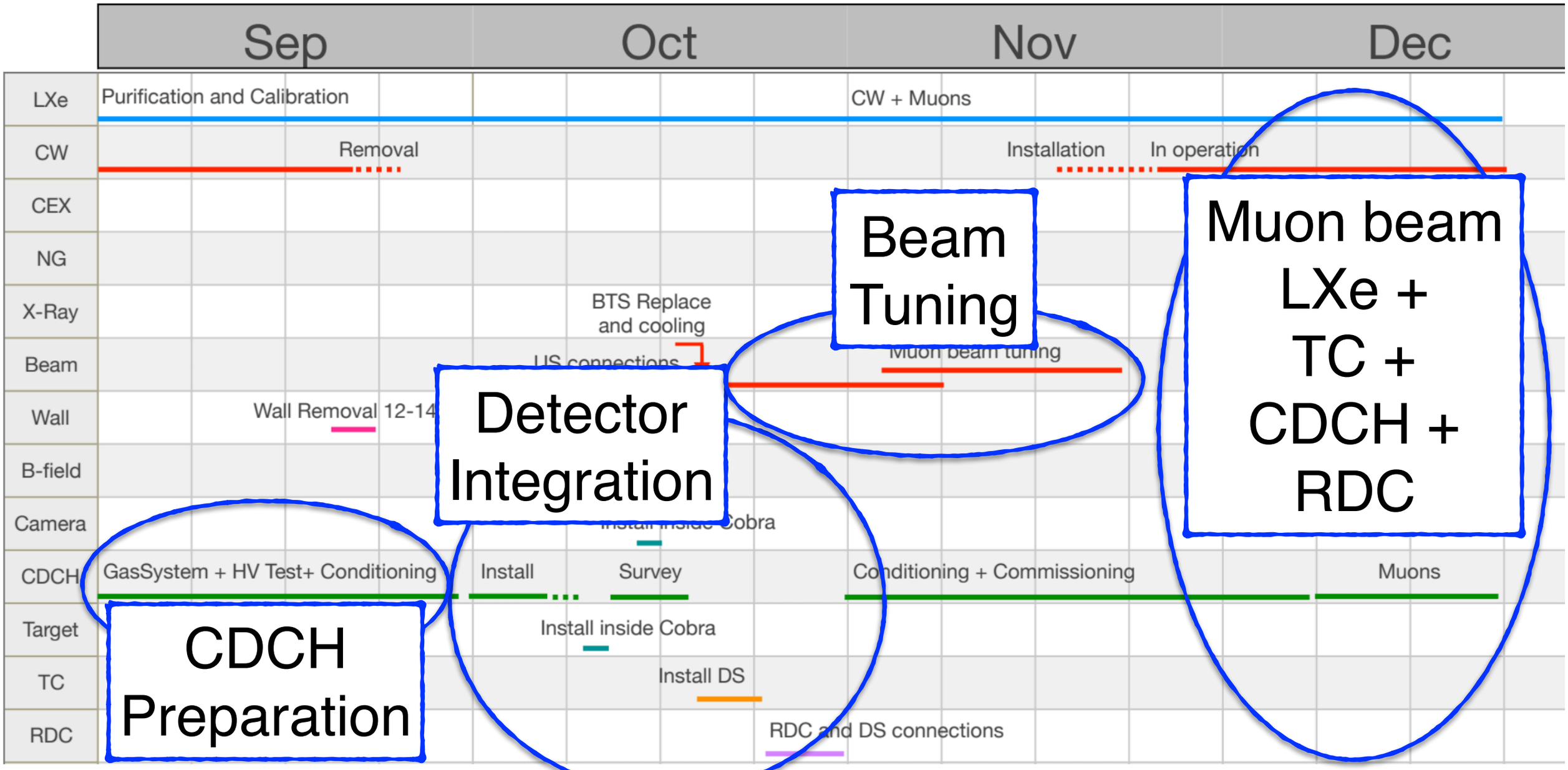
Prospects & Summary

- MEG II Detector integration in October 2018, and muon beam time in November - December with limited no. of electronics

- Mass production of the readout electronics will be next year.
- Engineering run and physics run will be started after that.

- The sensitivity of the MEG II experiment will exceed the current limit with a few month data, and will be improved by one order of magnitude with three years data

Prospects 2018



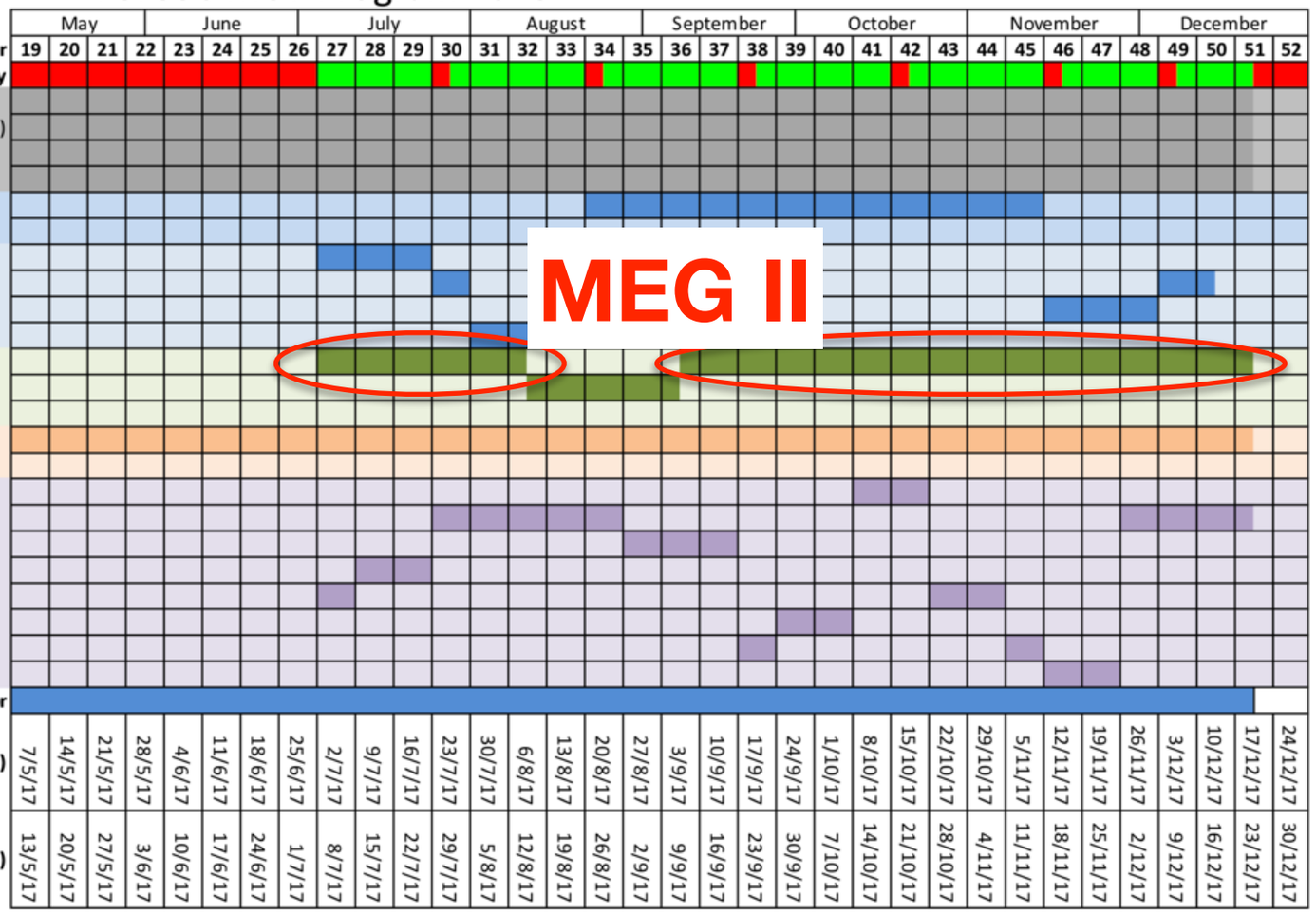
Beam time in 2018

- Beam time in 2018 for MEG II is allocated as requested (by Stefan)

PSI 590 MeV Program 2018

Last update: Feb 14th, 2018, S. Ritt <stefan.ritt@psi.ch>
http://www.psi.ch/ltp/FacilitiesEN/schedule_2017.pdf

		PSP	
PiM3	MuSR (GPS&LTF)		Amato (coord.)
PiE3	MuSR high field		Scheuermann (coord.)
MuE1	MuSR (GPD)		Amato (coord.)
MuE4	MuSR (LEM)		Prokscha (coord.)
PiE1-1	MuSR (Dolly)		Amato (coord.)
	Muonium	5203.32730.001	Knecht
PiE1-2	R-16-01.1 muX	5203.32730.001	Knecht
	Tests	5203.32730.001	Antognini
	Muonium	5203.85763.010	Soter
	VOXES	5203.85763.010	Scordo
PiE5	R-99-05.2 MEG	5201.32030.001	Mori
	R-12-03.1 Mu3E	5201.32030.002	Schoening
	R-16-02.1 HyperMu	5201.32030.006	Antognini
UCN	R-05-03.1 nEDM		Kirch
PiM1	R-12-03.1 Mu3E	5203.85763.010	Schoening
	R-12-01.2 MUSE	5203.85763.010	Gilman
	Praktikum	5203.85763.010	Grab
	Praktikum	5203.85763.010	Steinkamp
	CMS Diamond Detectors	5203.85763.010	Hits
	Micro Rwell	5203.85763.010	Bencivenni
	Tracking Calorimeter	5203.85763.010	Losekamm
	Irradiation	5203.85763.010	Hajdas



HIPA operation in 2018-2020

PAUL SCHERRER INSTITUT PSI

HIPA operation

Betrieb Protonen-Anlagen 2018-2020

	2018												2019												2020											
	Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
Beschleuniger	Resonator 2						Betrieb						Resonator 4						Betrieb						Verstärker				Betrieb							
max. Strahlstrom							2.0 mA												2.0 mA										2.4 mA							
Beamdump	neuer BHE1																		Dauereinsatz																	
Target E							4cm												slanted oder 6cm										slanted oder 4cm (zeitweise 6cm?)							
SINQ Betrieb	Shutdown						Betrieb						SINQ Upgrade												SINQ Upgrade				Betrieb							
Target Nr.					Target 13																						Target 13 (evtl. Target 14)									
UCN Betrieb							Testexperimente												(Test-) Experimente										n2EDM Betrieb							
Myonen (LMU&LTP)							Betrieb												Betrieb										Betrieb							

: Umbau : Betrieb

B. Blau, BSQ

Stand: 28.09.2017