WG4 - muon physics

SUMMARY &QUESTIONS

Robert Bernstein (FNAL)
Naohito Saito (KEK)
Giovanni Signorelli (INFN Pisa)

NuFact 2012, Williamsburg, VA, USA July 23–28 2012

WILLIAM &MARY

Jefferson Lab
EXPLORING THE NATURE OF MATTER

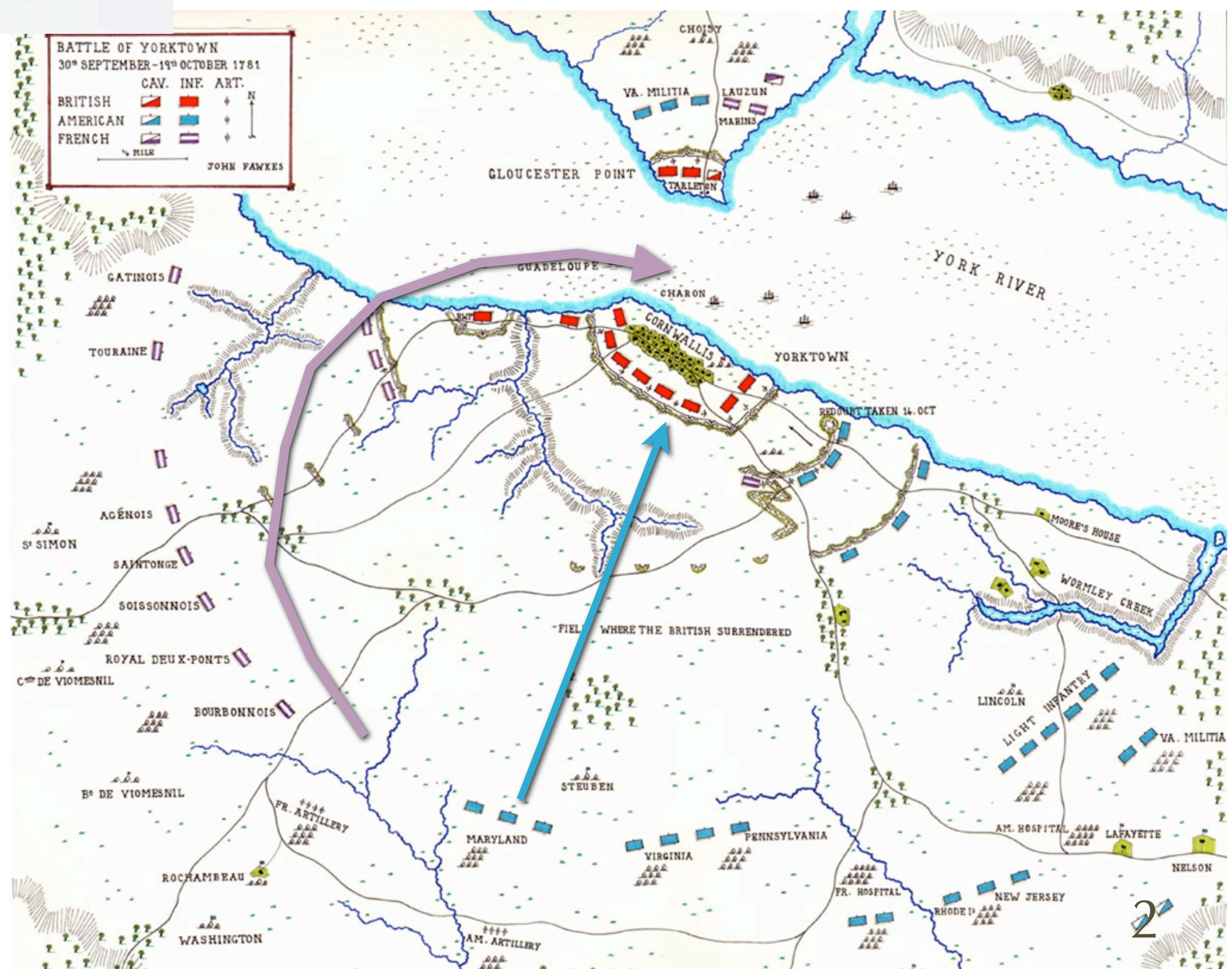
Muon physics

- A Neutrino Factory is also a Muon Factory

B-factory: E at CM = Y(4S)
e^+(3.5 GeV) e^-(8 GeV)
$\sigma(\tau\tau)$~0.9nb, $\sigma(bb)$~1.1nb
A B-factory is also a τ-factory!

Kiyoshi Hayasaka

- $p + \text{target} \rightarrow \begin{matrix} \pi \rightarrow \mu\nu \\ K \rightarrow \mu\nu \end{matrix}$



Yorktown battlefield

Muon physics

- charged Lepton Flavour Violation (cLFV)
  - $\mu \to e\gamma$, $\mu \to eee$
  - $\mu 2e$, $\tau \to$ cLFV

7 talks

- Precision experiments
  - μHFS
  - g–2
  - μ-Lamb Shift
  - μ-capture

8 talks

- Muon Facilities
  - present & future

16 talks

- Muon applications

2 talks

total of 33 talks

Including WG1+4 (1 session 3 talks)
& WG3+4 (3 sessions 11 talks)

μ-applications

- Get a proton beam
- Shoot it on a target
- Compute the particle flux
- Find a mine to put an experiment

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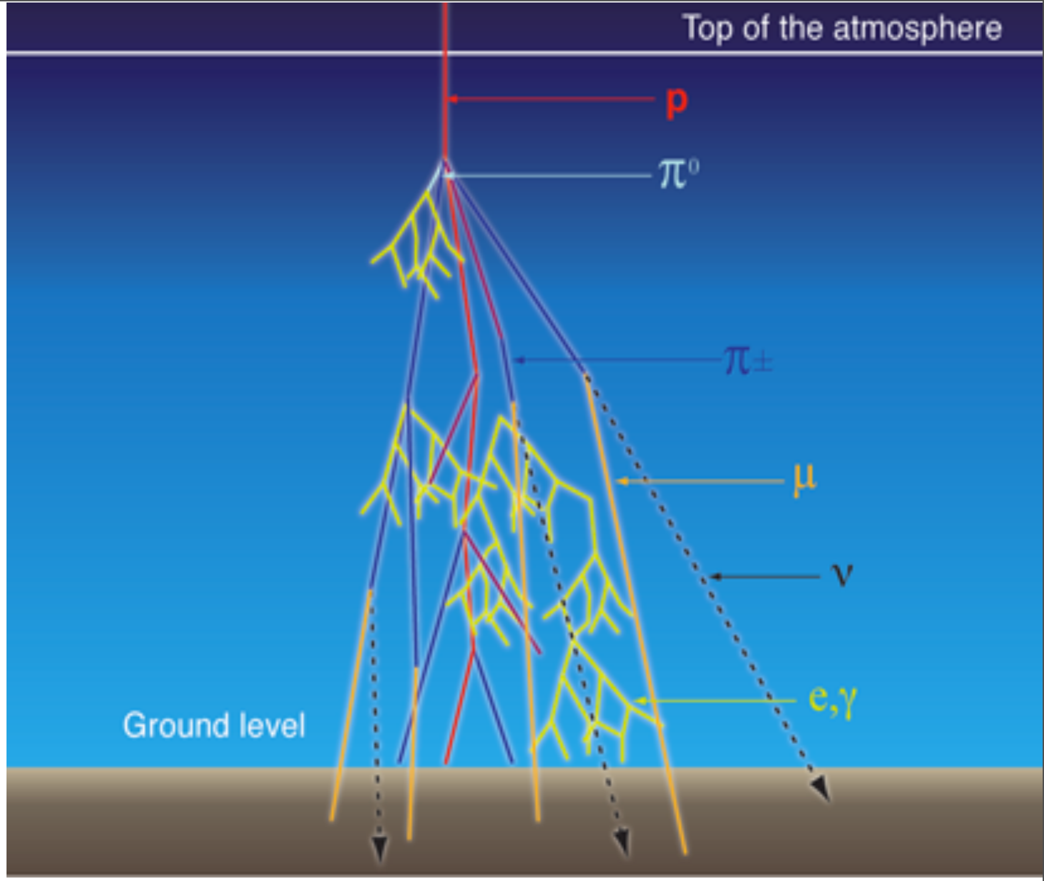
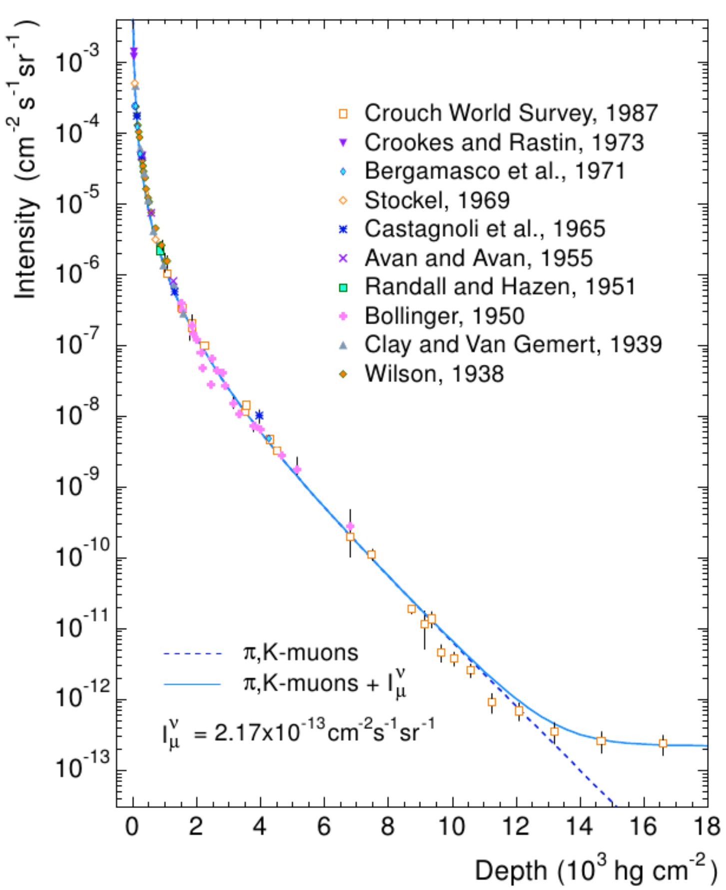


CR Muon Intensity vs. Depth

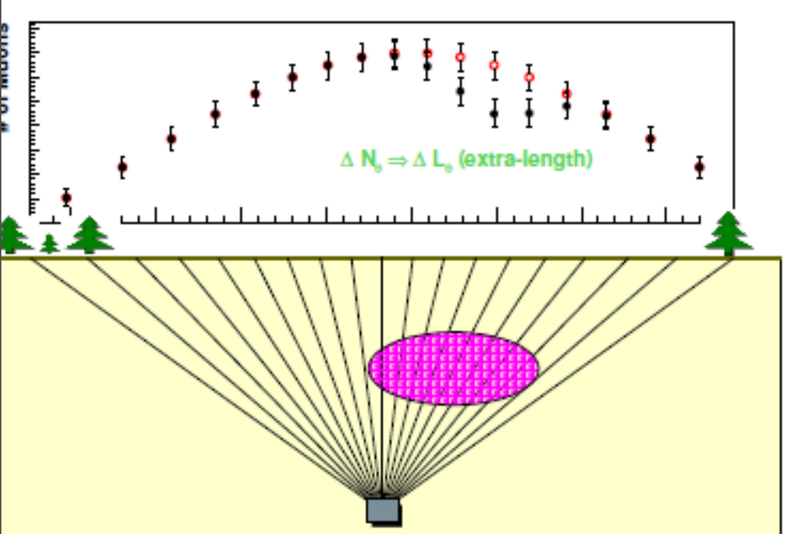


E. V. Bugaev *et al.*,PRD 58 054001 (1998)

Search for ores

- Nothing comparable with present technology
- Does not give false positives

Forward Model



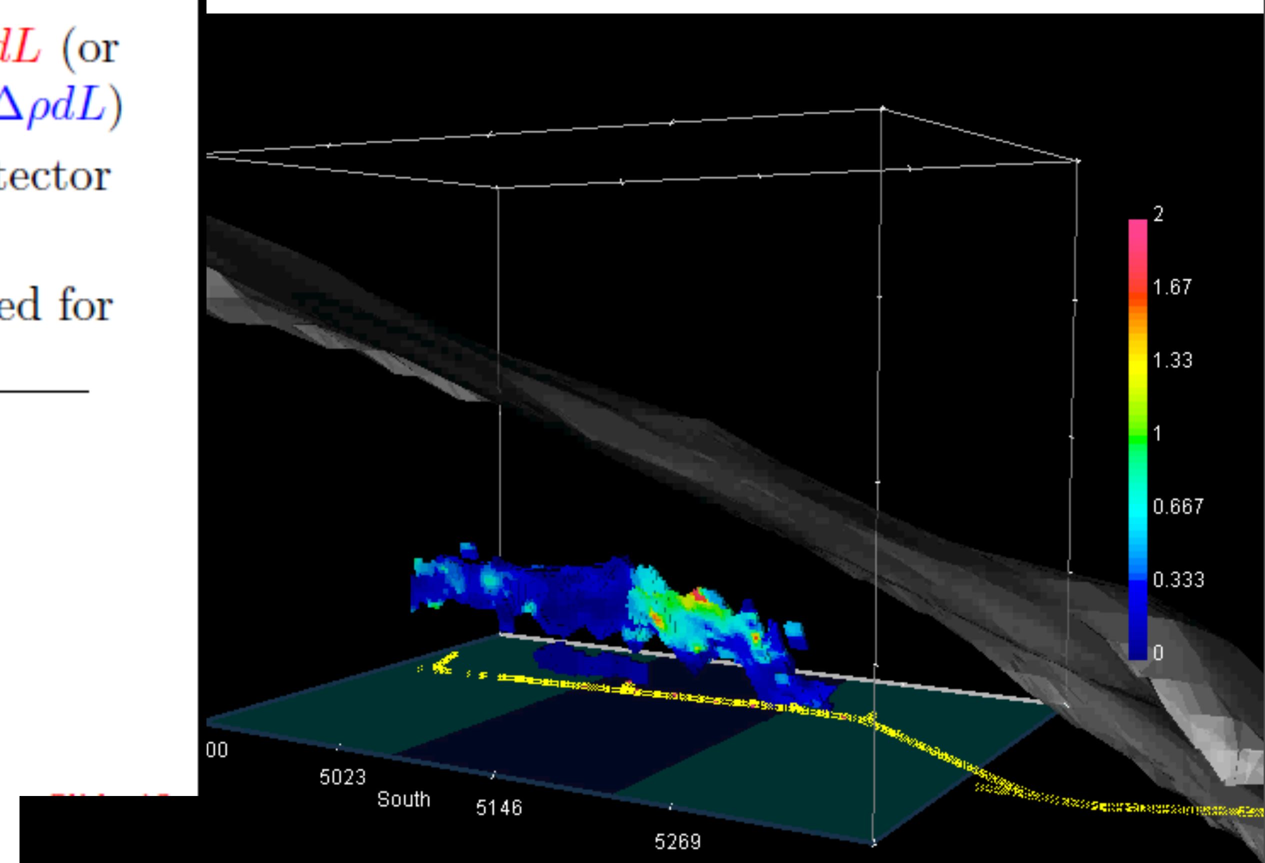
Forward model

- Given topological data and target ore body
- Calculate mass length $\int \rho dL$ (or anomalous mass length $\int \Delta\rho dL$)
- Calculate muon flux at detector level
- Estimate muon counts (used for uncertainty estimate)

Simulation samples

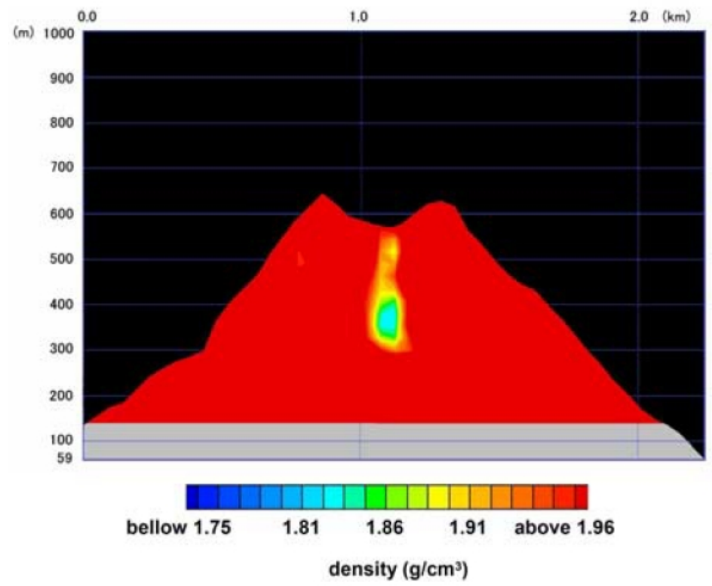
- Based on forward model, generate noise data
- Used to design survey and perform NULL hypotheses tests

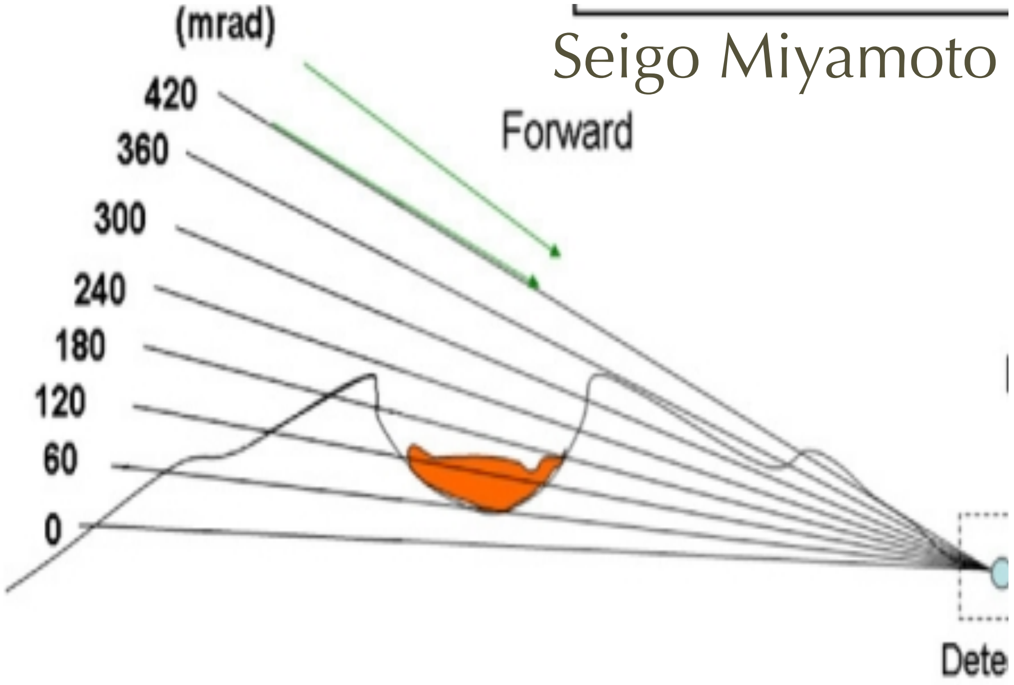
Doug Bryman



Volcanoes & earthquakes

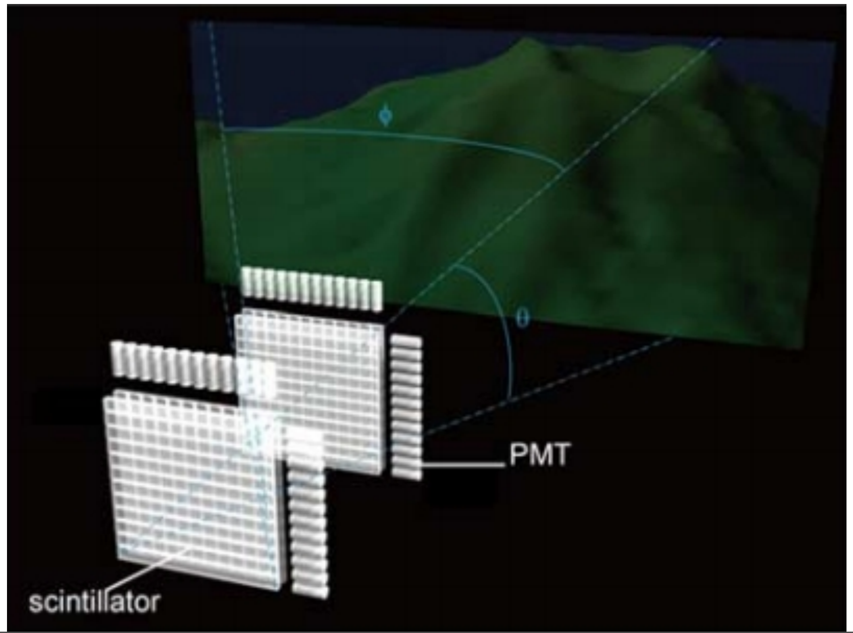
- Imaging of volcanoes, seismic faults with unprecedented resolution
  - aiming at "real time"

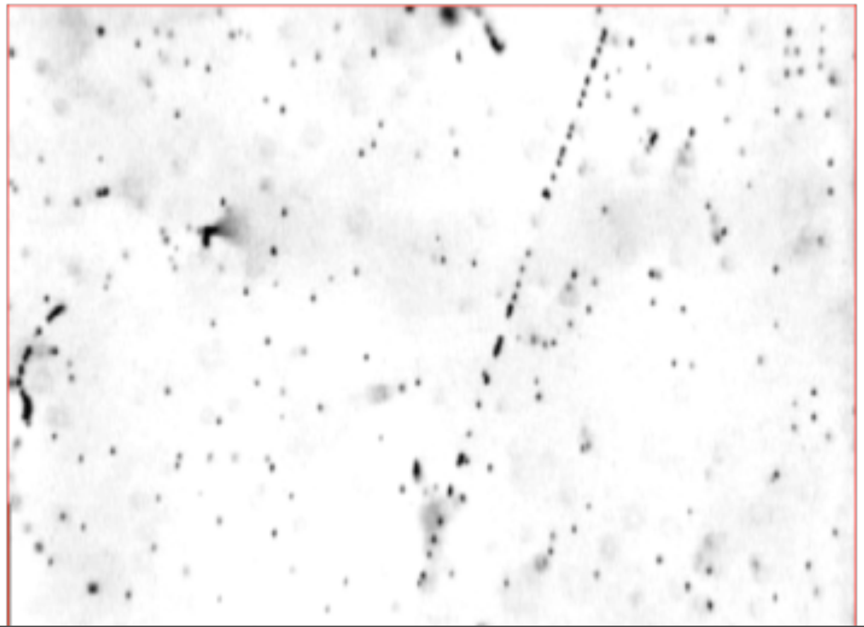




Seigo Miyamoto

- Detector technology derived by neutrino physics
  - Opera experience with scintillator bar array + emulsion





Questions from Nufact 2011

What we expect at Nufact12

- MEG
  - New results
- μ-e conversion
  - Mu2e
  - COMET
  - R&D : MuSIC
- J-PARC MUSE activities : H-Line
  - Mu HFS
  - DeeMe
  - g-2/EDM
- FNAL g-2
- PSI : $\mu \rightarrow eee$, muEDM
- τ-sector
  - combined Belle and BaBar results
  - Prospects for Belle-II and SuperB
- Precision tests
  - μ lifetime (MuLAN)
  - cross sections (MuSUN)

- R&D of intense muon source
  - MuSIC
  - Laser ionization of Muonium
  - Muon production
  - Pion collection
  - Leading work towards muon collider
  - MICE related talk
  - Muon production and cooling

Joint with WG2,3

- PRISM/PRIME
- High intensity proton driver physics / intensity frontier physics
  - Rare K
  - nEDM

Joint with WG1

- Theory
  - Reflect LHC search results to the physics scope of the WG
  - Implications due to new measurements of θ_{13}, δ_{CP}

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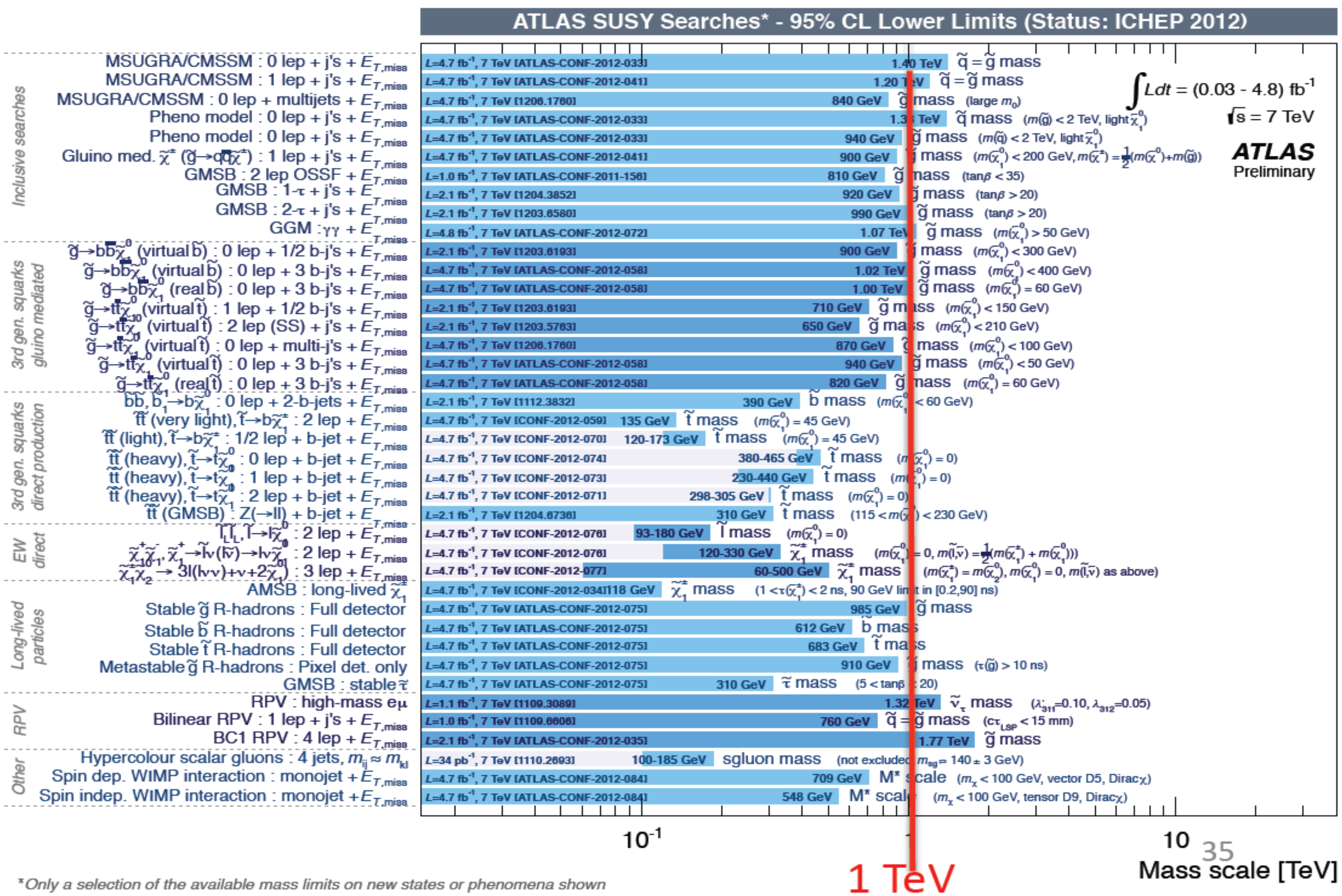
Joint with WG1

Highlights of 2012

- ϑ_{13} is big
- (SM) Higgs boson is at 125 GeV
- SUSY not seen so far

Bob Tschirhart



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Courtesy Andy Parker, ICHEP-2012

Focus of 2012

- How μ-physics is influenced by the news?

Lorenzo Calibbi

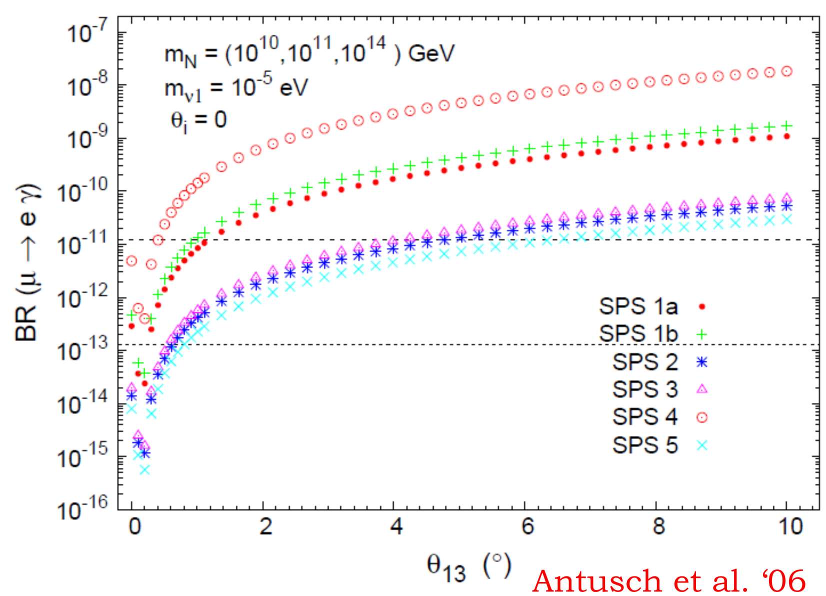
θ_{13} dependence

$\boxed{\text{Type I}}$: in general the connection between seesaw couplings and the PMNS is 'washed out' by the matrix R Casas et al '10

However, theoretically motivated examples where the correlation is there:

- Trivial mixing from RHν (i.e. R~**1**) :

$$\Rightarrow \quad \mathrm{BR}(\mu \to e\gamma) \propto \left|(y_k^N)^2\, U_{\mu k} U_{ek}^*\right|^2$$ (hierarchical RHν → k=3)



Antusch et al. '06

LFV vs θ_{13} Lorenzo Calibbi (MPP)

- Not only a direct dependence on the angle

Focus of 2012

- But also the mass scale that is tested is far beyond the LHC

Lorenzo Calibbi

Introduction

$\boxed{\text{Why LFV?}}$

- Unambigous signal of New Physics
- Stringent test of NP models
- It probes scales far beyond the LHC reach: $\boxed{\mathrm{BR}(\mu \to e\gamma) < 10^{-13}}$

Process	Relevant operators	Pres. Bound on Λ $(c=1)$	Fut. Bound on Λ $(c=1)$
$\mu \to e\gamma$	$\frac{c}{\Lambda^2}\frac{m_\mu}{16\pi^2}\overline{\mu}_L\sigma^{\mu\nu}e_R F_{\mu\nu}$	48 TeV	107 TeV
$\mu \to eee$	$\frac{c}{16\pi^2\Lambda^2}(\overline{\mu}_L\gamma^\mu e_L)(\overline{e}_L\gamma^\mu e_L)$	17 TeV	166 TeV
	$\frac{c}{16\pi^2\Lambda^2}(\overline{\mu}_L e_R)(\overline{e}_R e_L)$	10 TeV	98 TeV
$\mu \to e$ in Ti	$\frac{c}{16\pi^2\Lambda^2}(\overline{\mu}_L\gamma^\mu e_L)(\overline{d}_L\gamma^\mu d_L)$	33 TeV	577 TeV
	$\frac{c}{16\pi^2\Lambda^2}(\overline{\mu}_L e_R)(\overline{d}_R d_L)$	59 TeV	1000 TeV

LC Lalak Pokorski Ziegler '12

$\boxed{\mathrm{BR}(\mu \to eee) < 10^{-16}}$ $\boxed{\mathrm{CR}(\mu \to e \text{ in Ti}) < 5\times 10^{-17}}$

LFV vs θ_{13}

Susan Gardner

Note too recent CMS limits [1205.0272] on pair-produced new particles at 95% CL:

$m_{\tilde{g}} > 1098$ GeV $m_{\tilde{t}} > 737$ GeV $m_{\tilde{\tau}} > 223$ GeV

In the absence of signals from the LHC, EDMs can give crucial insight.

Note talk by K. Blum.

S. Gardner (Univ. of Kentucky) EDMs@Project X NuFact 2012, W&M/JLab 6 / 1

Focus of 2012

Lorenzo Calibbi

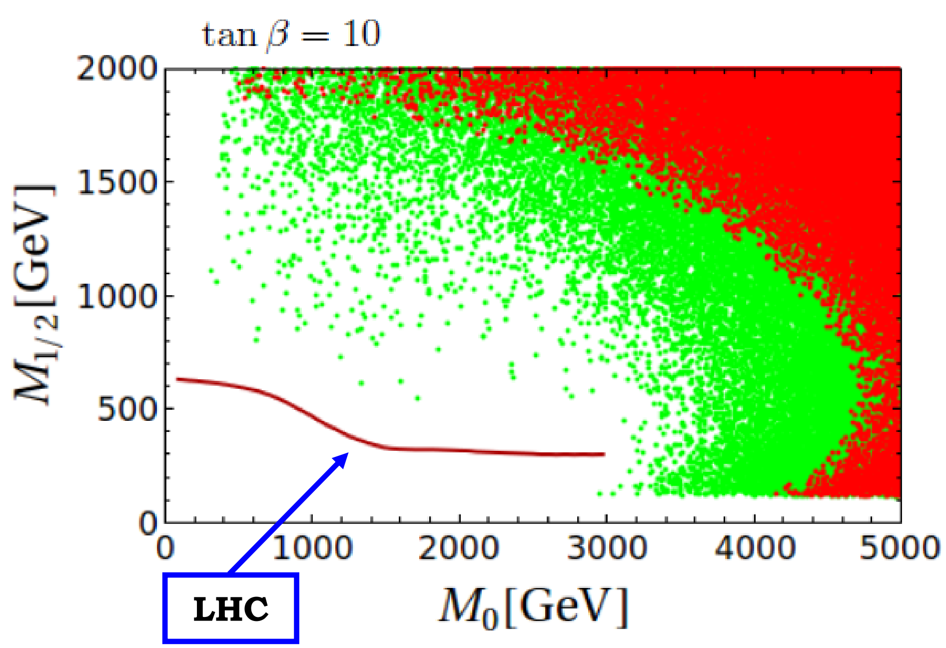
- But also the mass scale that is tested is far beyond the LHC

θ_{13} dependence

$\boxed{\text{Type I}}$: in general the connection between seesaw couplings and the PMNS is 'washed out' by the matrix R Casas et al '10

However, theoretically motivated examples where the correlation is there:

- SO(10) GUT ('PMNS mixing' case): $\mathrm{BR}(\mu \to e\gamma) \propto \left| y_t^2 \, U_{\mu 3} U_{e3}^* \right|^2$



LC Chowdhury Masiero Patel Vempati, to appear

$$m_0 \in [0,\ 5]\ \mathrm{TeV}$$
$$\Delta m_H \in \begin{cases} 0 & \text{for mSUGRA} \\ [0,\ 5] & \text{for NUHM1} \end{cases}$$
$$m_{1/2} \in [0.1,\ 2]\ \mathrm{TeV}$$
$$A_0 \in [-3m_0,\ +3m_0]$$
$$\mathrm{sgn}(\mu) \in \{-,+\}$$

$$\boxed{|U_{e3}| = 0.11}$$

$$\boxed{124.5\ \mathrm{GeV} \lesssim m_h \lesssim 126.5\ \mathrm{GeV}}$$

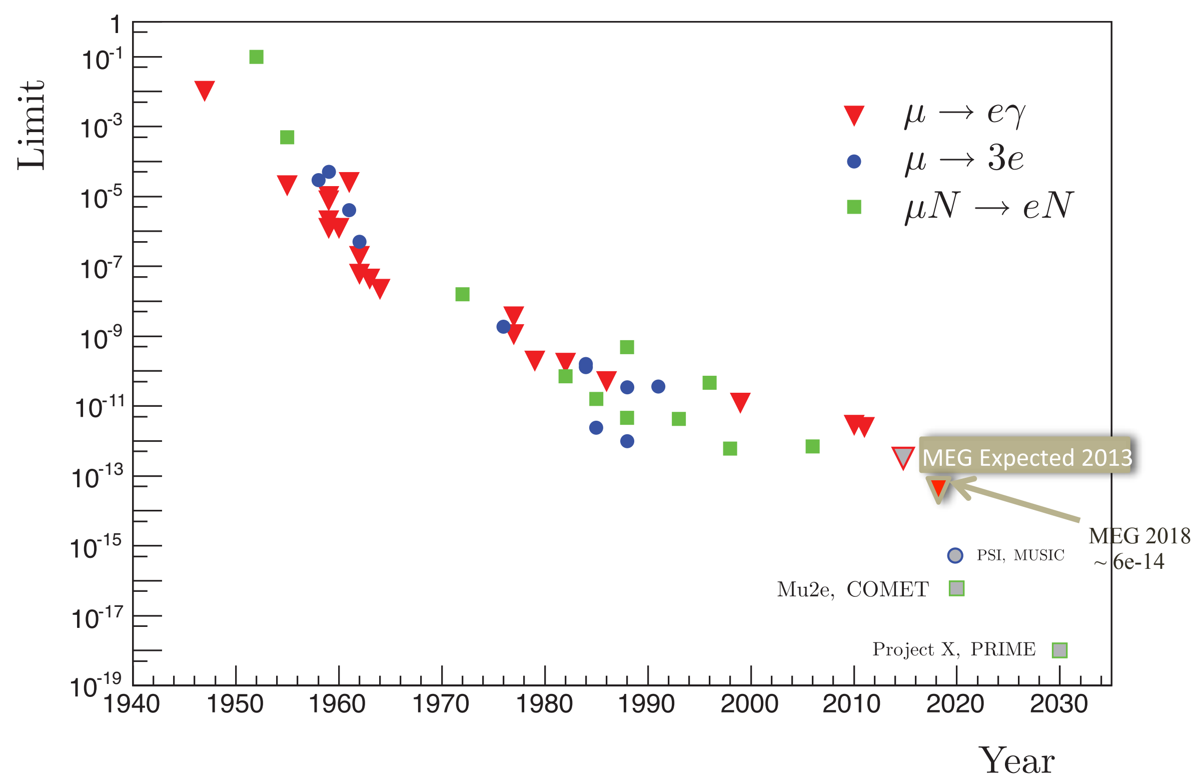
cLFV Experiments

R. Bernstein

CLFV Experiments

- CLFV in the Muon System

History of $\mu \to e\gamma$, $\mu N \to eN$, and $\mu \to 3e$



10^4 improvement followed by additional X100 followed by…

R. Bernstein, NuFact 2012 WG4
Introduction

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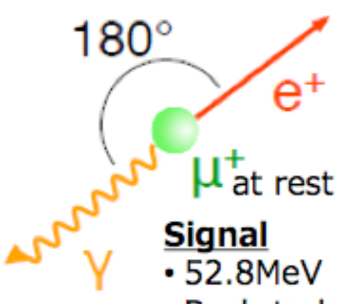
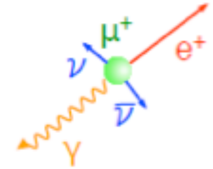
μ→eγ search status

Elisabetta Baracchini

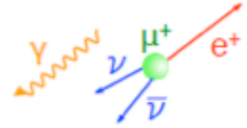
μ→eγ :experimental signature



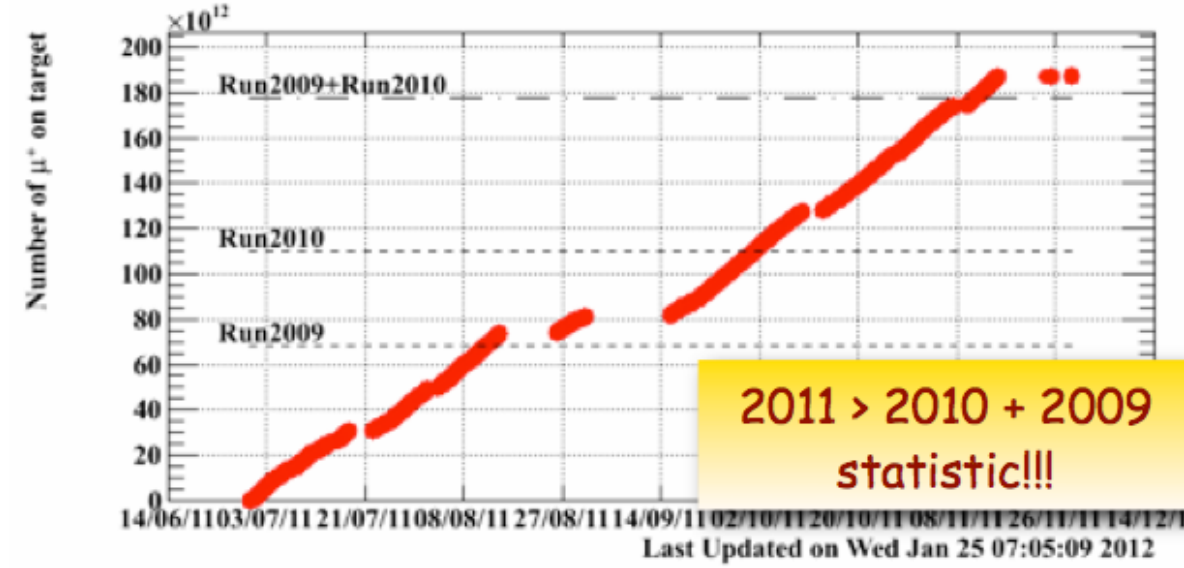
Signal
- 52.8MeV
- Back-to-back
- Time coincidence

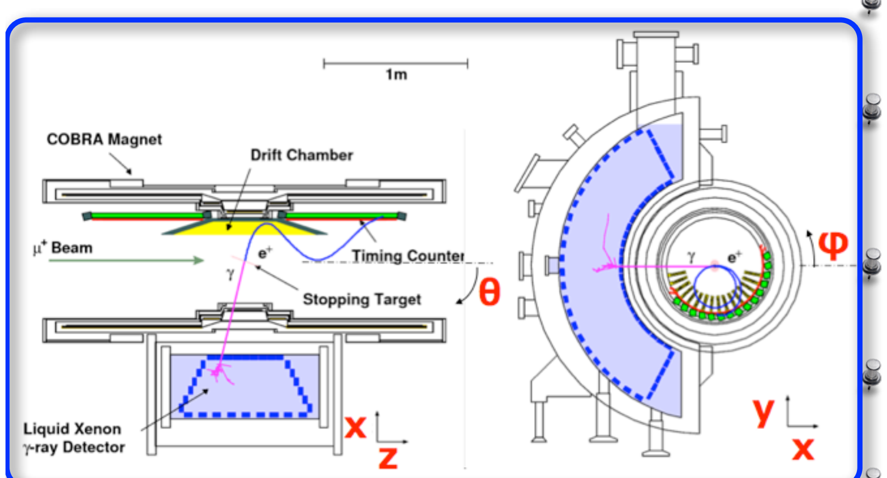


Physics BG
(radiative muon decay)
- <52.8MeV
- Any angle
- Time coincidence

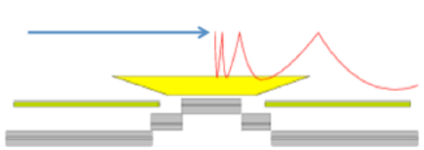


Accidental BG
- <52.8MeV
- Any angle
- Random

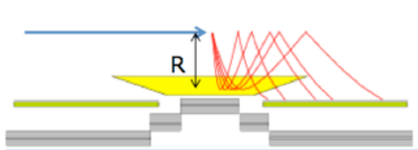




- Most intense DC muon beam of 3 x 10^7 muon/s at PSI
- Quasi-solenoidal spectrometer & low mass drift chamber for e+ kinematic measurement
- Scintillator bars and fibers for e+ timing read by PMT/APD
- Liquid Xenon calorimeter for photon detection read by PMT
- ~10^7 fully efficient trigger bkg suppression



e+ quickly swept out



Constant bending radius independent of emission angles

Gradient B field instead of uniform B field for good momentum resolution and high pile up rejection

Conclusions & Prospects

- 2009 + 2010 MEG data analysis consistent with null signal
- Most stringent UL on LFV improved by a factor 5

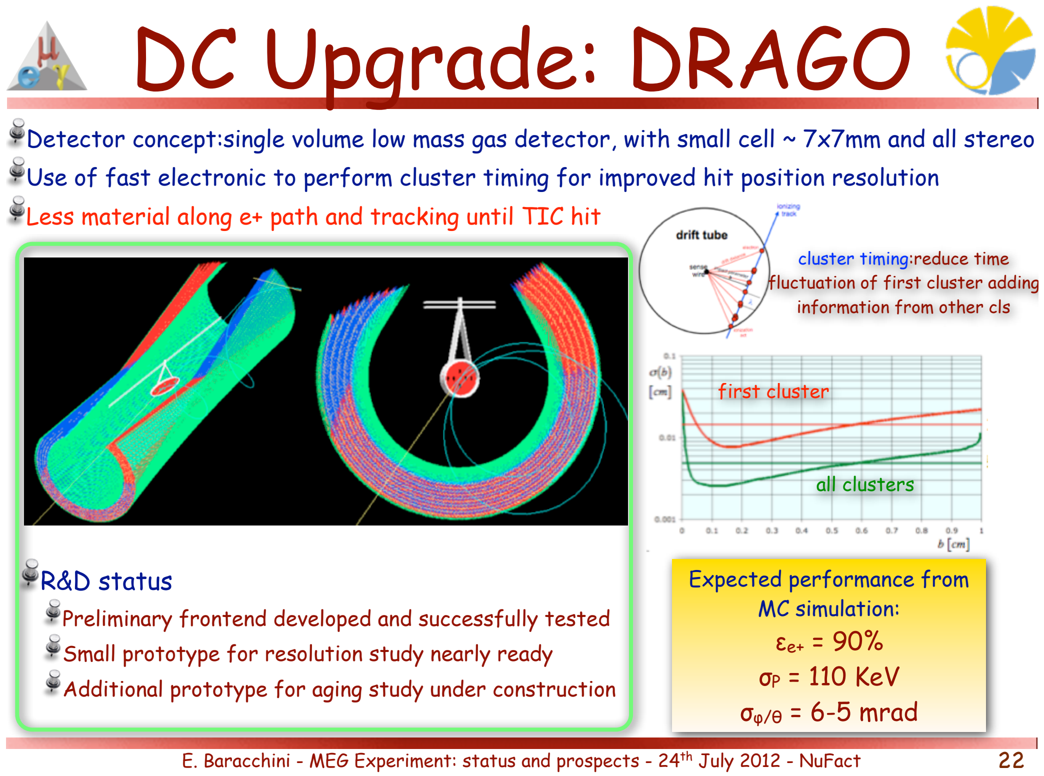
  $BR(\mu^+ \to e^+ \gamma) < 2.4 \times 10^{-12}$ @ 90% CL
- MEG 2011 dataset > 2010 +2009 statistic with improved trigger, DAQ and DC noise conditions

  Expected sensitivity with 2011 data: 1 x 10^{-12}
  Stay tuned!! :)
- 2012 data taking starting this week
- Upgrade proposal getting finalized and soon to be presented to INFN (this week) and PSI (end of the year)

  Upgrade proposal sensitivity $O(10^{-14})$

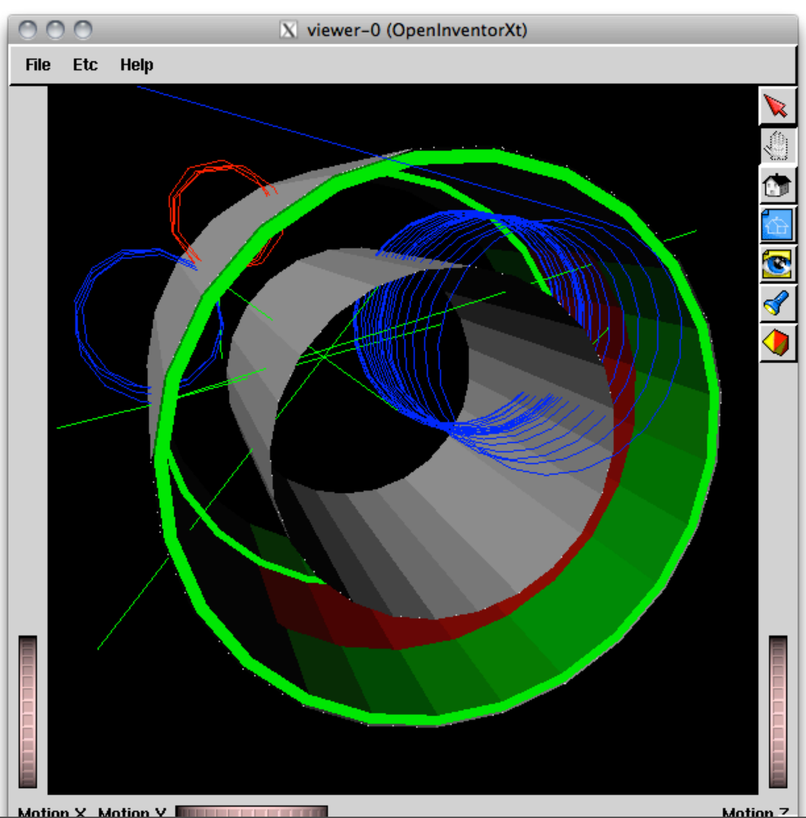
μ→eγ search status

- MEG Upgrade towards (5÷6) x 10^{-14}



Elisabetta Baracchini

- New Experiments?
  - convert the photon



Other problem:

Need target extended in z (~150 cm) since gamma is pointing in from so far out.

Putting calorimetry / tof On sides doesn't work…

They could go inside converter if they're not too thick

Fritz DeJongh

Which is the ultimate reach of a $\mu \to e\gamma$ search?

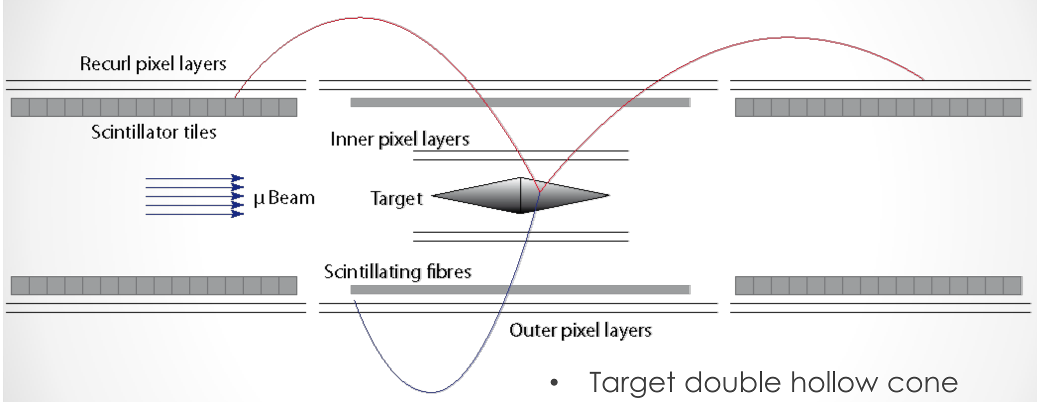
And, in the meanwhile we want to hear, in 2013
- The updated MEG result
- The sensitivity and schedule of the new upgrade
- Calibration & alignment of the new chambers

Photon conversion promising, but still problems
- How to deal with the high rate of positrons?
- pattern recognition?
- background from positron AIF?
- Which are the characteristics of the new tracker?
- At which muon momentum?

New experiment to search for μ→eee?

- LOI at PSI for a new μ→eee experiment (HV-MAPS + fibers)
- Need 10^9 μ/sec. Two stages

The Mu3e Experiment



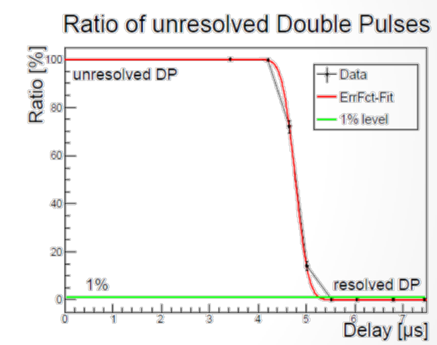
- Muon beam O(10^9/s)
- Helium atmosphere
- 1 T B-field

- Target double hollow cone
- Silicon pixel tracker
- Scintillating fiber tracker
- Recurl station
- Tile hodoscope

Dirk Wiedner, Mu3e collaboration 7/24/2012 14

Double Pulse Resolution

- Ratio of
  - resolved to
  - unresolved double pulses
- 5.27 ± 0.01 μs



Dirk Wiedner, Mu3e collaboration 7/24/2012 23

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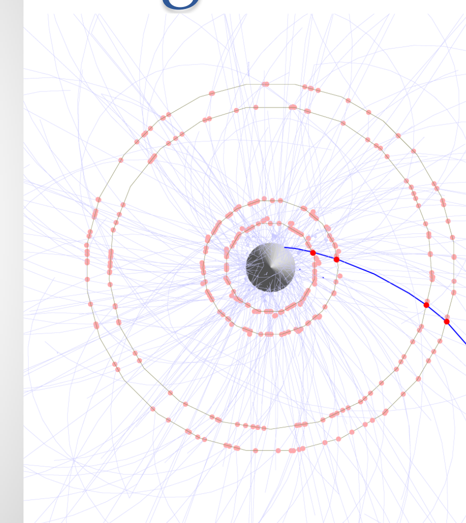

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Inner Double Layer

Very stable self supporting structure

Dirk Wiedner, Mu3e collaboration 7/24/2012 27

Schedule

- **2012 Letter of intent** to PSI, tracker prototype, technical design, technical design report
- **2013** Detector **construction**
- **2014** Installation and **commissioning** at PSI
- **2015** Data taking at up to a few **10^8 μ/s**
- **2016+** Construction of **new beam-line** at PSI
- **2017++** Data taking at up to **$3 \cdot 10^9$ μ/s**

Dirk Wiedner, Mu3e collaboration 7/24/2012 31

Dirk Wiedner

Which is the ultimate reach of a $\mu\to eee$ search?

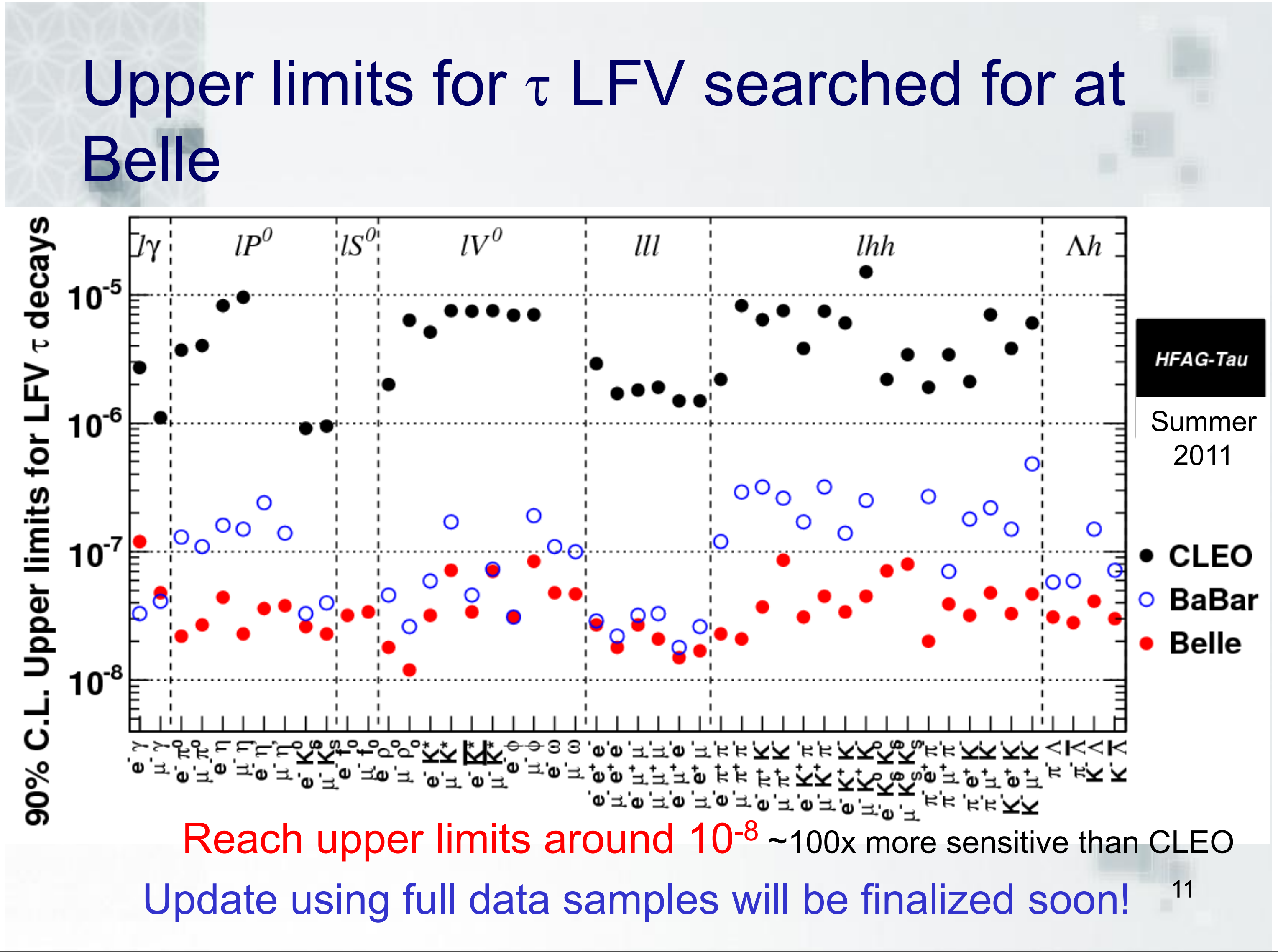
And, in the meanwhile we want to hear, in 2013

- Update on the $\mu\to eee$ detector
- Tracking with silicon/fibers
- Track reconstruction

Is there a way to merge a $\mu\to eee$ with an ultimate sensitivity $\mu\to e\gamma$?

cLFV in the τ-sector

- τ-LFV: τ has many LFV decays → sensitive to many models
- Belle is working on the final result of τ→μγ: expected late 2012
  - 980 fb^{-1}
  - not only Υ(4S) but also Υ(1S), Υ(2S), Υ(3S), Υ(5S)
  - Combination of Babar and Belle results
- SuperKEK physics starts end 2015
- Which is the status of SuperB?



Kiyoshi Hayasaka

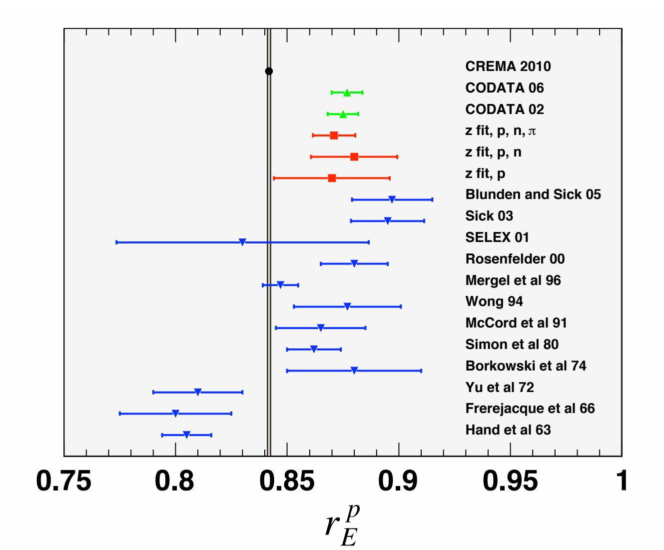
Final limit on τ-cLFV decays?
- combination of Belle & Babar

Status of SuperKEK, SuperB

High precision muon physics

- MuLan, TWIST, μCap → 2011
- Proton radius measurement with μ-H Lamb shift

the proton radius puzzle



- inferred from muonic H

- inferred from electronic H

- extraction from e p, e n scattering, ππNN data (this talk)

- previous extractions from e p scattering (as tabulated in PDG)

R. Hill

Summary

The proton radius is still a puzzle.

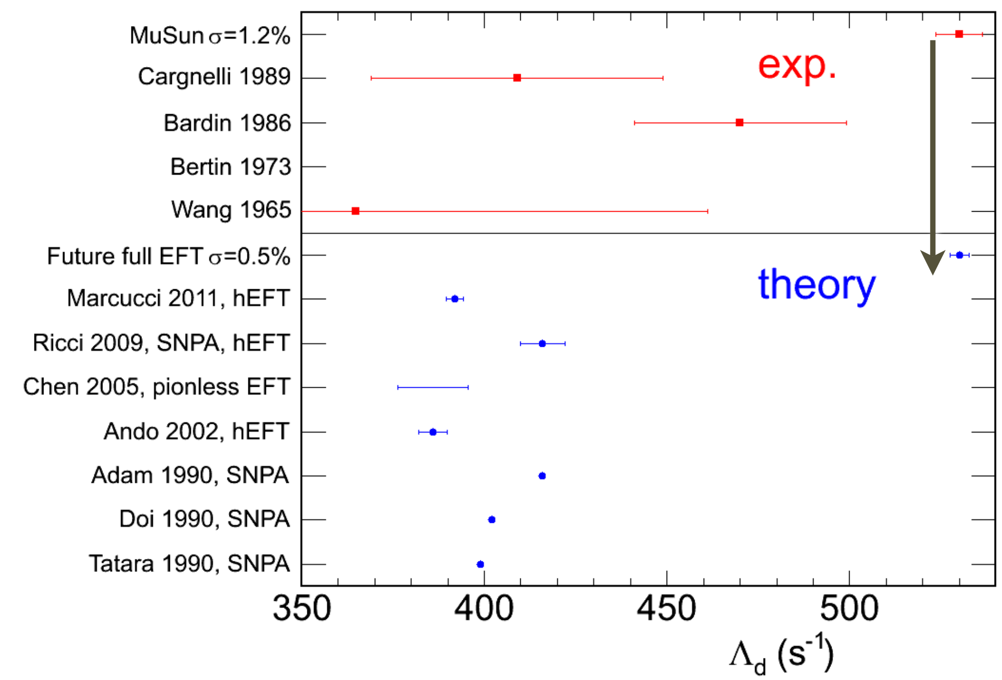
- ...ndane resolution may be ~5σ shift in Rydberg (less mundane resolutions postulated)

- μSun: μ-capture rate on *d* better than 1.5%
  - pp fusion, SNO, ^{3}H β-decay

Status and Outlook

- Summer 2011, Run 4: 5e9 good muon stops with decay electron – First analysis pass recently completed
- Fall 2012: Commission newly reconstructed beam line at PSI
- Summer 2013, Run 5: After modest upgrades to TPC, preamps, triggering scheme - Collect another 1E10 muon stops
- 2014, Run 6?: TBD

$$\mu^- d \to \nu_\mu n n$$

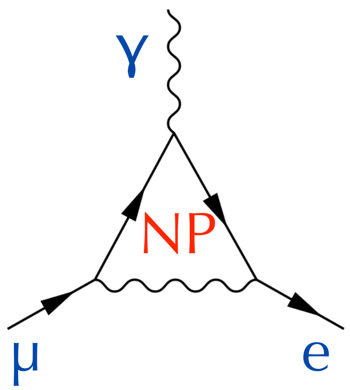


Robert Carey

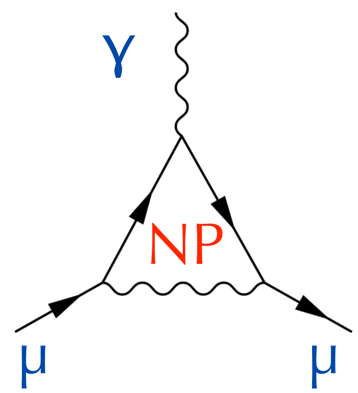
Keep us up-to-date

Status of $(g\text{–}2)_\mu$ and d_μ

- Measuring g–2 is possible through a series of “magic” things



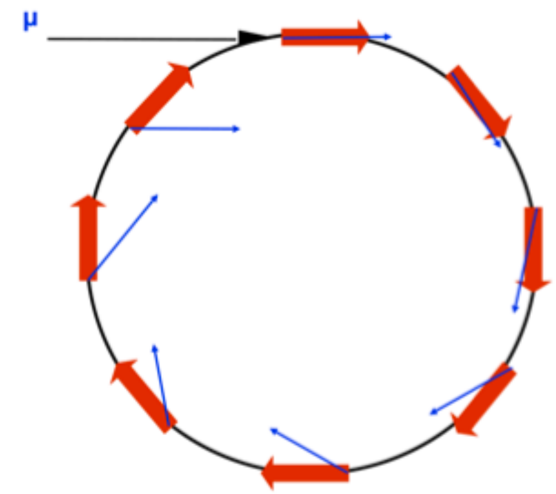
$\mu \to e\gamma$

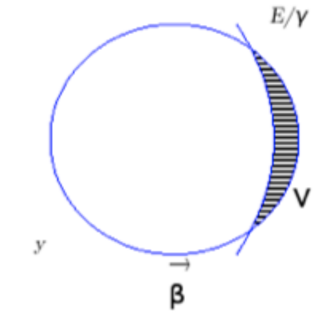


$(g-2)_\mu$

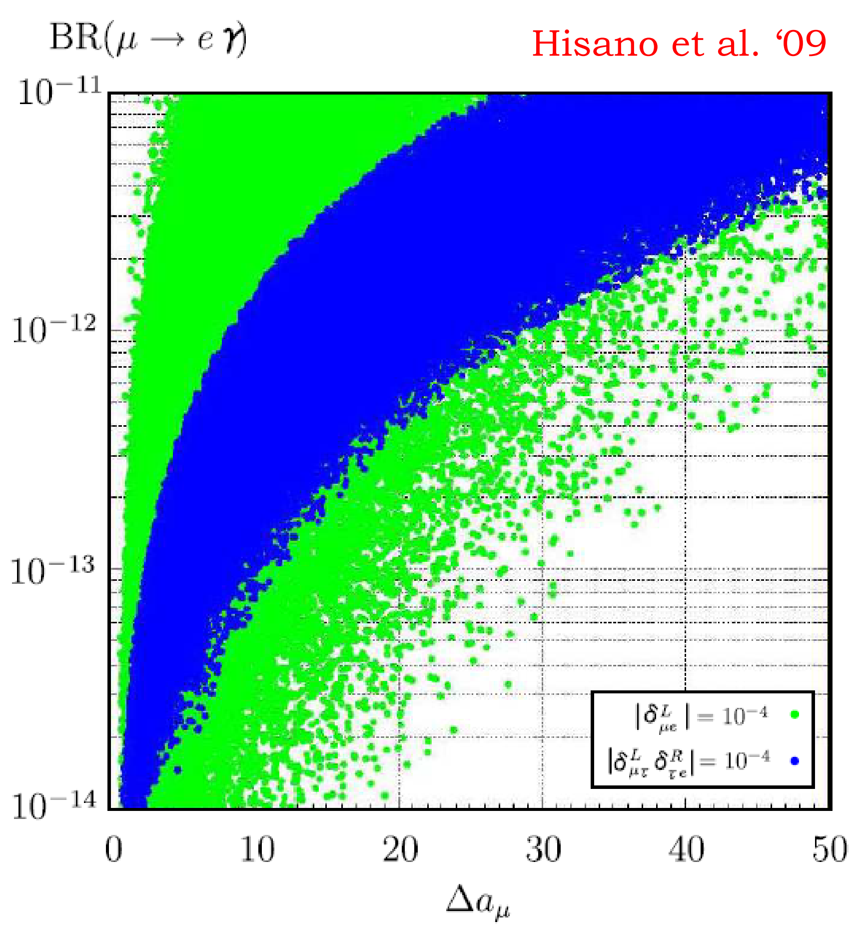
$$\frac{dS^\mu}{d\tau} = g\frac{e}{2mc}F^{\mu\nu}S_\nu + \left(\frac{g-2}{2}\right)\frac{e}{m^3c^3}F^{\alpha\beta}S_\alpha P_\beta P^\mu.$$

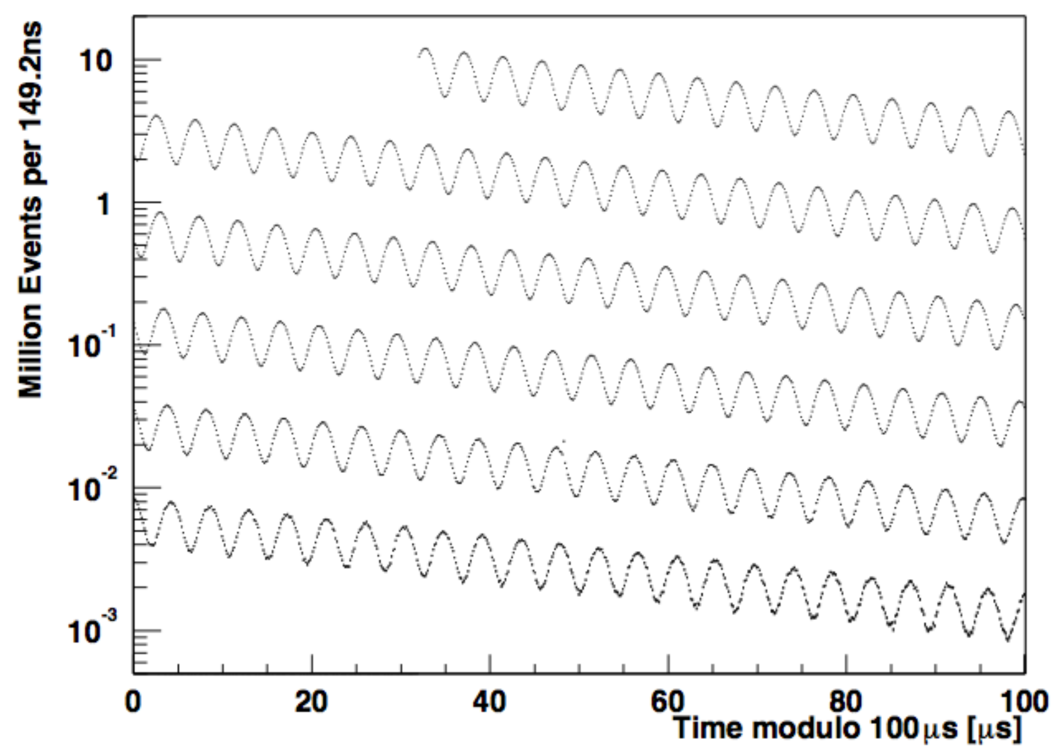
$$\omega_a = \omega_s - \omega_R = \left(\frac{e}{mc}\right)\left[a_\mu \mathbf{B} + \left(\frac{1}{1-\gamma^2} - a_\mu\right)\boldsymbol{\beta}\times\mathbf{E}\right]$$





Cut in E_e
→
cut in angle

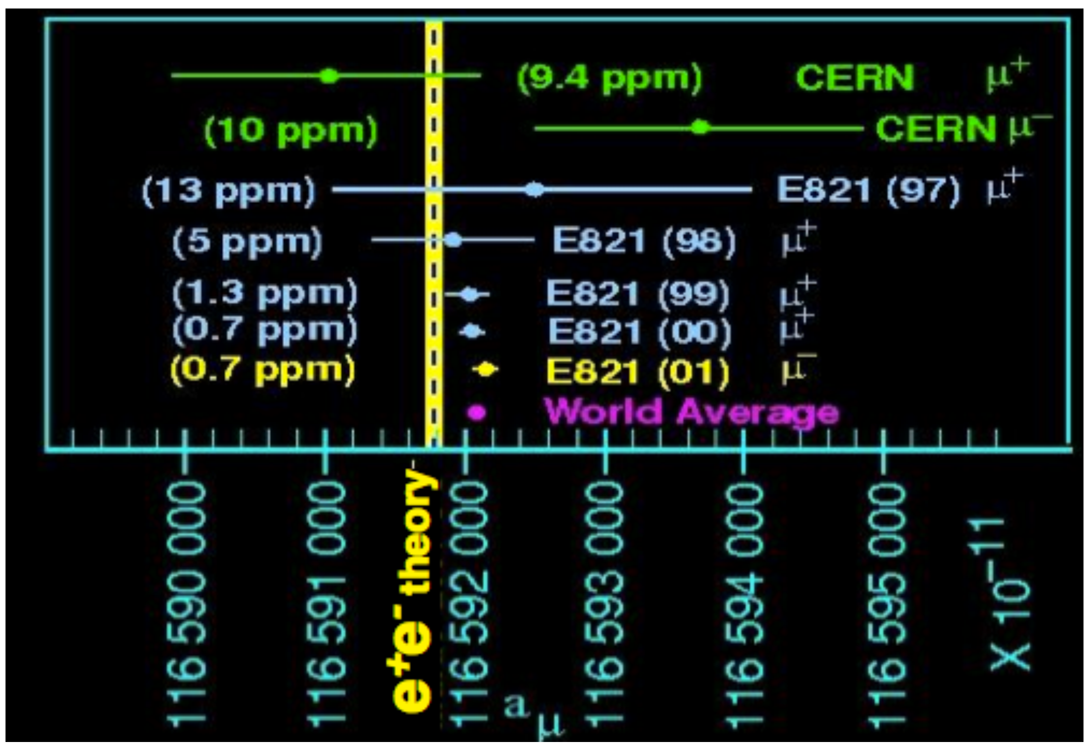




Status of $(g–2)_\mu$ and d_μ

- QED contriibution calculated at 5 loops in May 2012

James Miller



QED now calculated to 5-loops!

Complete Tenth-Order QED Contribution to the Muon $g-2$

Tatsumi Aoyama,[1,2] Masashi Hayakawa,[3,2] Toichiro Kinoshita,[4,2] and Makiko Nio[2]

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[4] *Laboratory for Elementary Particle Physics, Cornell University, Ithaca, New York, 14853, U.S.A*

(Dated: May 29, 2012)

We report the result of our calculation of the complete tenth-order QED terms of the muon $g-2$. Our result is $a_\mu^{(10)} = 753.29\ (1.04)$ in units of $(\alpha/\pi)^5$, which is about 4.5 s.d. larger than the leading-logarithmic estimate 663 (20). We also improved the precision of the eighth-order QED term of a_μ, obtaining $a_\mu^{(8)} = 130.8794\ (63)$ in units of $(\alpha/\pi)^4$. Using the best non-QED value of α, we obtain the standard model prediction $a_\mu(\mathrm{SM}) = 116\ 591\ 840\ (59) \times 10^{-11}$, to be compared with the measured value $a_\mu(\mathrm{exp}) = 116\ 592\ 089\ (63) \times 10^{-11}$. The difference $a_\mu(\mathrm{exp}) - a_\mu(\mathrm{SM}) = 249\ (87) \times 10^{-11}$ is about 2.9 s.d.

PACS numbers: 13.40.Em,14.60.Ef,12.20.Ds

- arXiv:1205.5370v2 [hep-ph] 27 May 2012
- 12,672 diagrams

(g–2) at FNAL

3.6 σ: Theory & Experiment must do better

James Miller

The New $g{-}2$ Experiment:

An experiment to Measure the Muon Anomalous Magnetic Moment

to ± 0.14 ppm Precision

- Experiment: E989 at Fermilab ≥ X4 better
  - relocate the storage ring to Fermilab (operations $)
  - use the p-bar beam line and debuncher storage ring (now called the delivery ring) as a long decay line.
- CD0 expected very soon.
- Building construction will begin in November 2012

James Miller

- Precision x4 (±0.14 ppm)

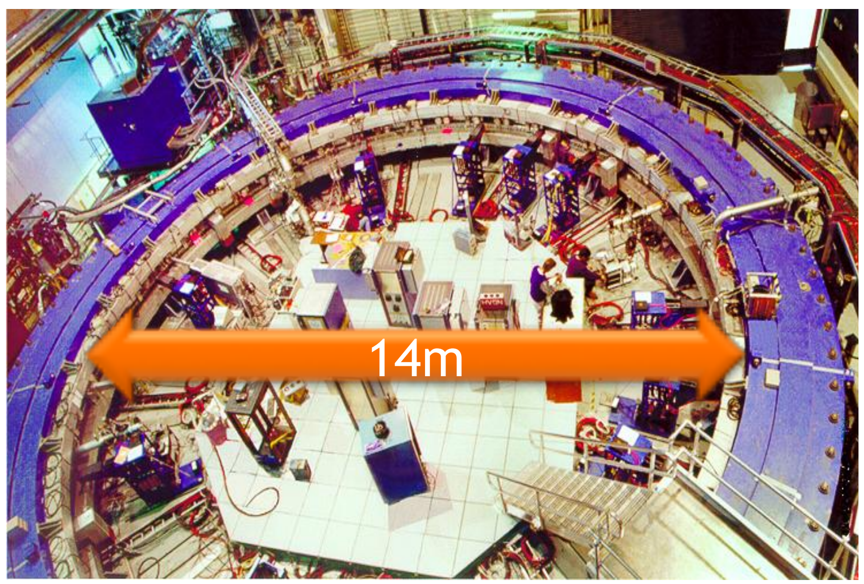
(g–2) in Japan

- g–2 J-Parc uses a completely different approach
  - Off magic momentum (no E fields)
  - Ultra-cold muons from muonium emission

Lower energy & Compact storage ring

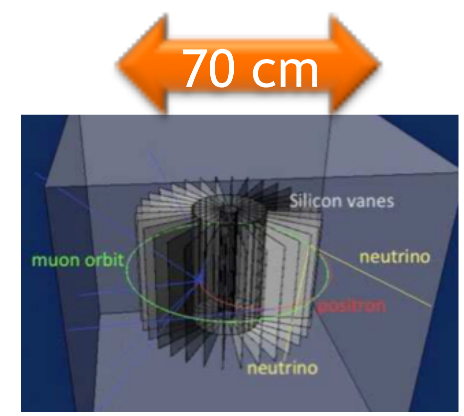
Tsutomu Mibe

BNL E821 / FNAL g-2



P= 3.1 GeV/c , B=1.45 T

J-PARC g-2



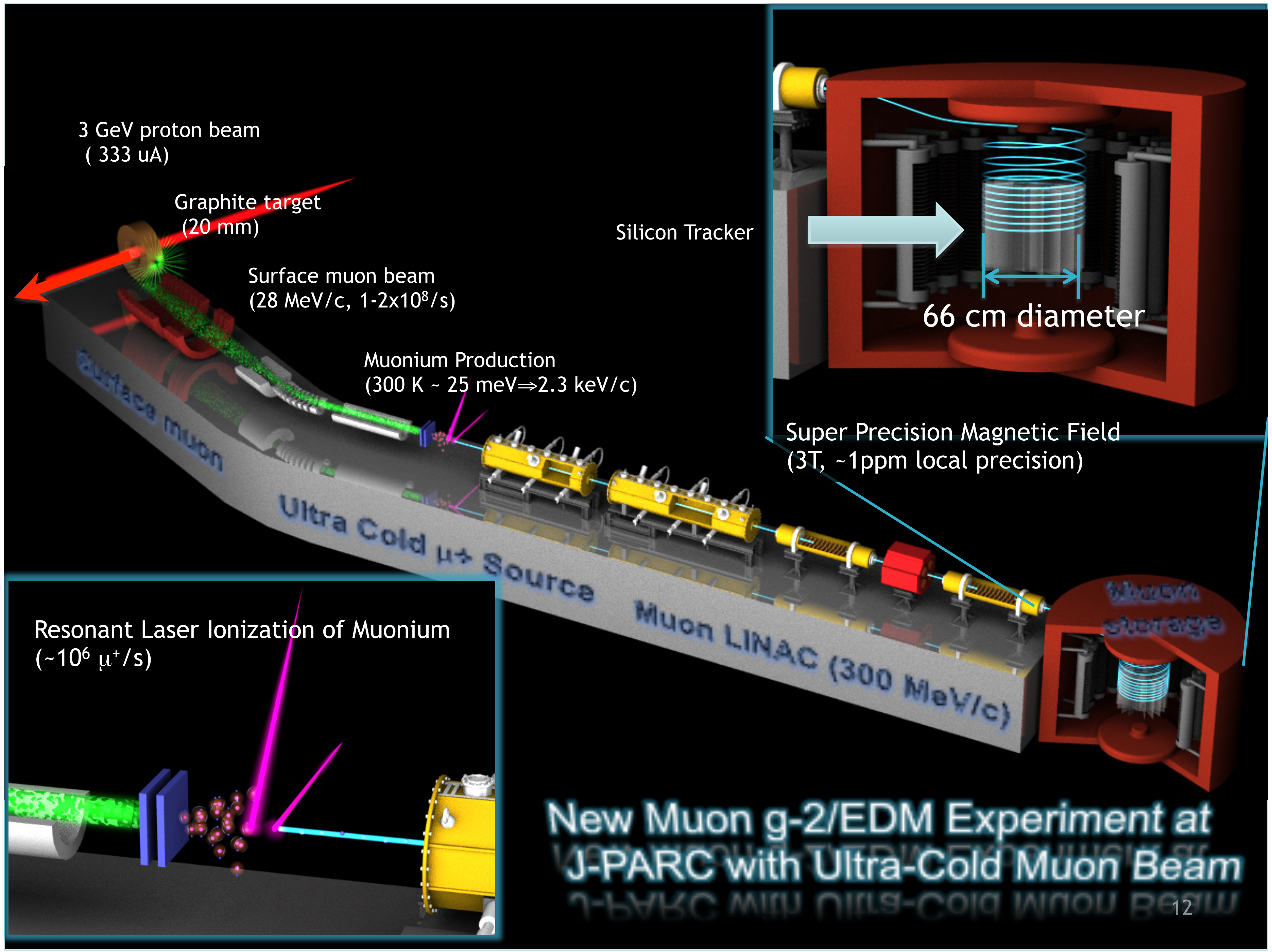
P= 0.3 GeV/c , B=3.0 T

- Advantages
  - Suited for precision control of B-field
    - Example : MRI magnet , 1ppm local uniformity
  - Possibility of spin manipulation
    - Effective to cancel various systematics
  - <u>Completely different systematics than the BNL E821 or FNAL</u>

(g–2) in Japan

Tsutomu Mibe

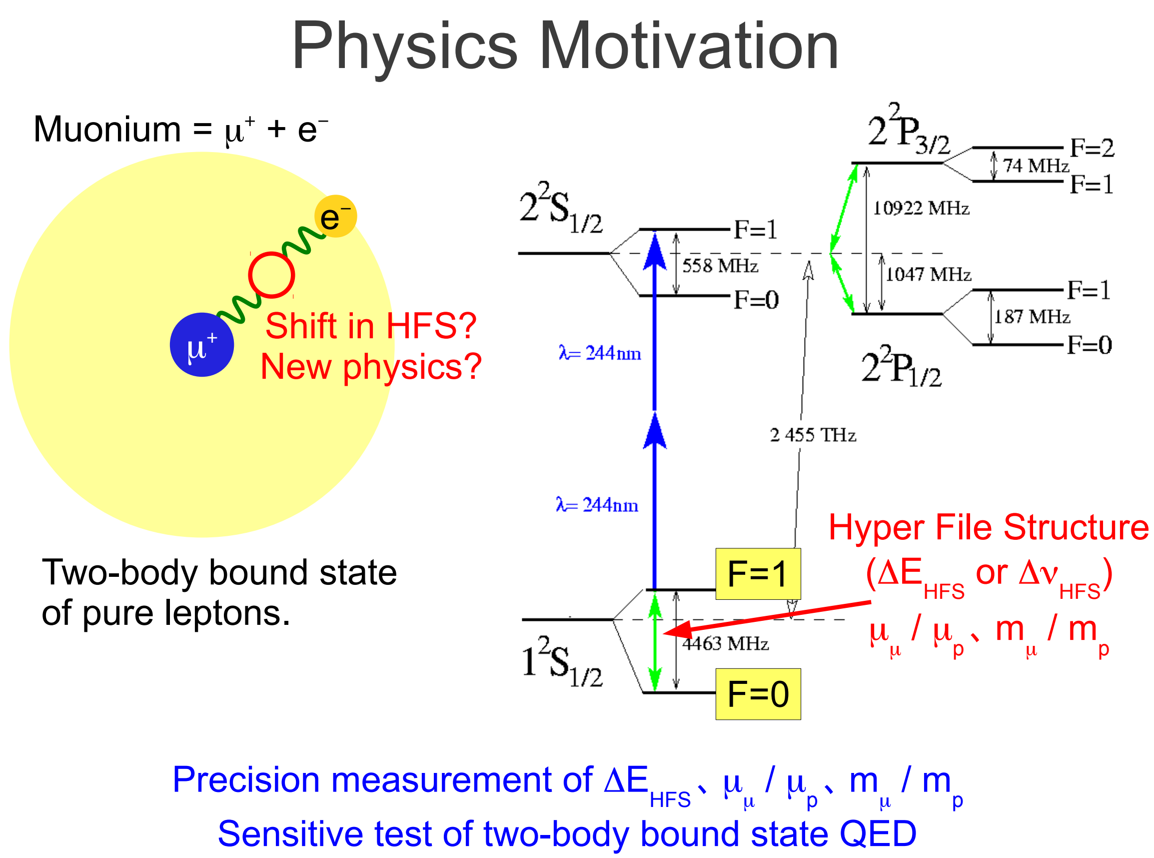
- Extremely important to reduce/understand systematics



- Dec 2011 CDR
- Jan 2012 stage 1 recommendation

2 complementary measurements ongoing

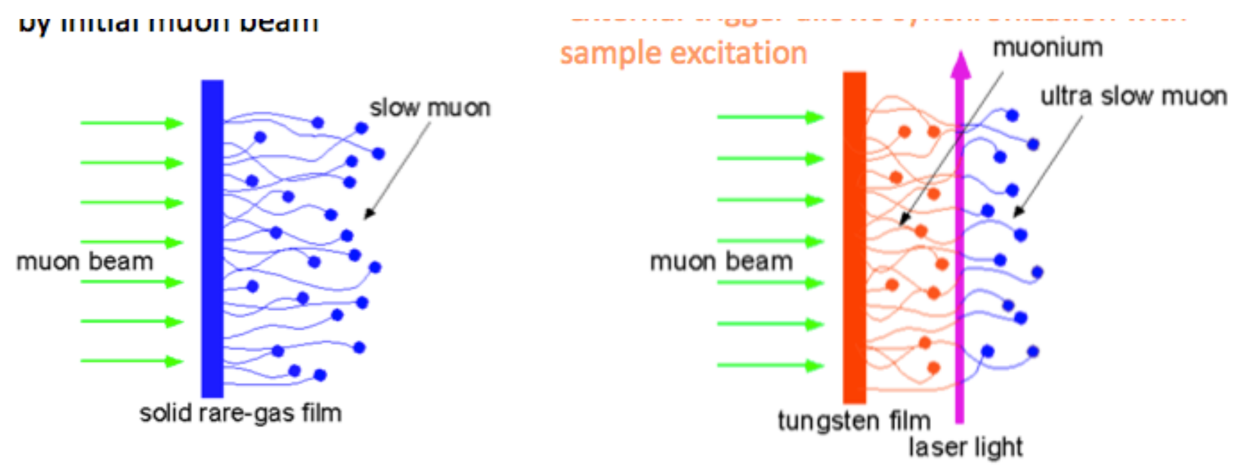
- μ-HFS input to g–2.
- Previous number from LAMPF 1999
  - statistics 107 ppb, B field 56 ppb
  - improve to <1 ppb
  - reach LAMPF statistics in 28 hours



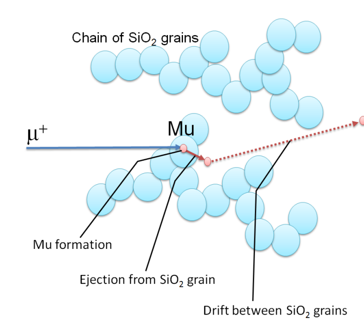
Yoshinori Fukao

- ultra-slow μ production at RAL.
  - cold moderator
  - muonium ionization

Dai Tomono



- Test for muonium ionization materials



- Efficiency still too low << 1%
- Suggestion to use metallized aerogel

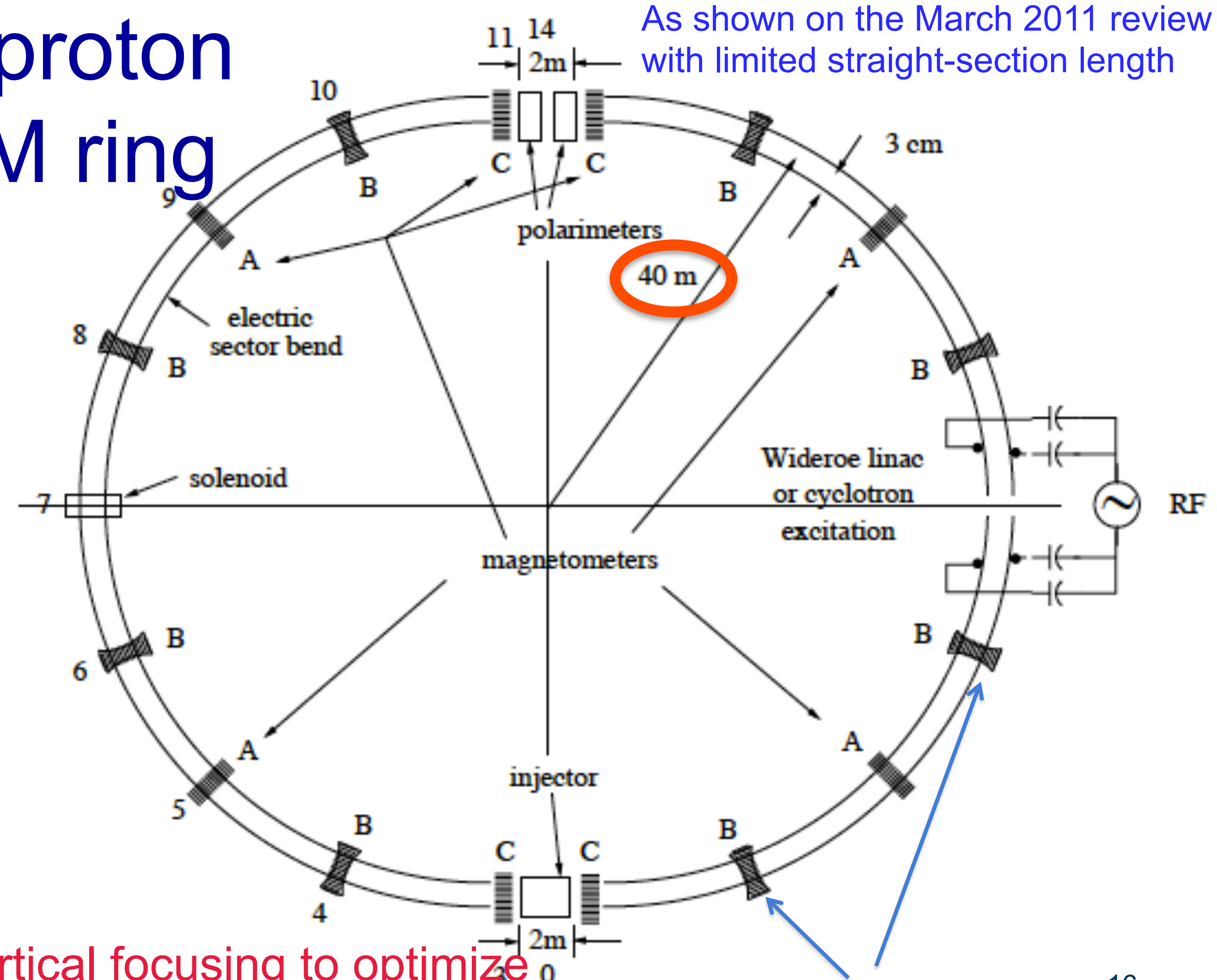
Proton EDM

- On the same line of dipole moment measurements
- Reverse E and B
- protons kept in orbit by electric field

Y. Semertzidis

The proton EDM ring

As shown on the March 2011 review with limited straight-section length



Weak vertical focusing to optimize SCT and BPM operation

B: quadrupoles [16]

Schedule in US and Japan

Detector design

New measurement of μHFS

Ultra-slow muons

- efficiency of the extraction
- polarization of extracted muons

Can be more specific in the different systematics

- magnetic field monitor

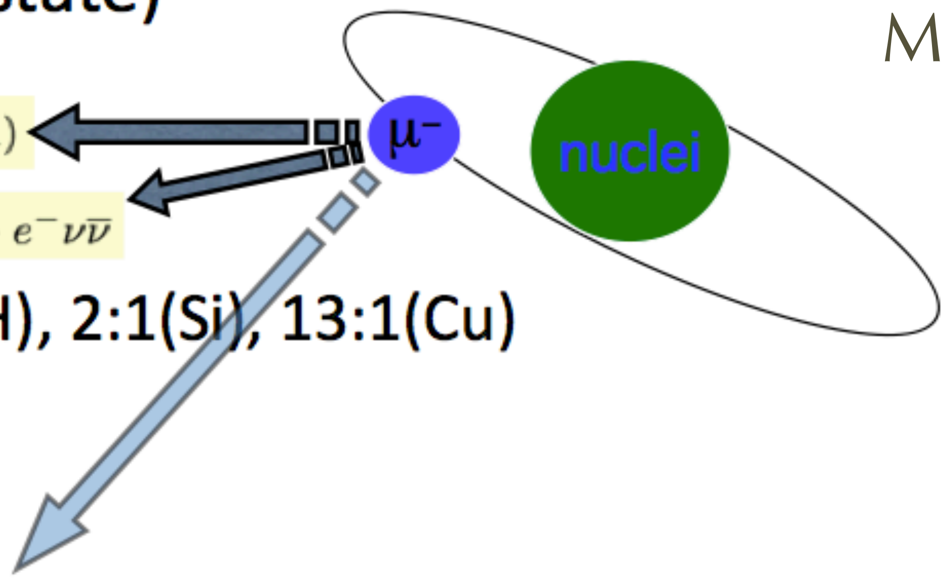
μ→e transition

- Muonic Atom (1S state)

Muon Capture(MC)

$\mu^- + (A,Z) \rightarrow \nu_\mu + (A, Z-1)$

Muon Decay in Orbit (DIO) $\mu^- \rightarrow e^- \nu \bar{\nu}$



Masa Aoki

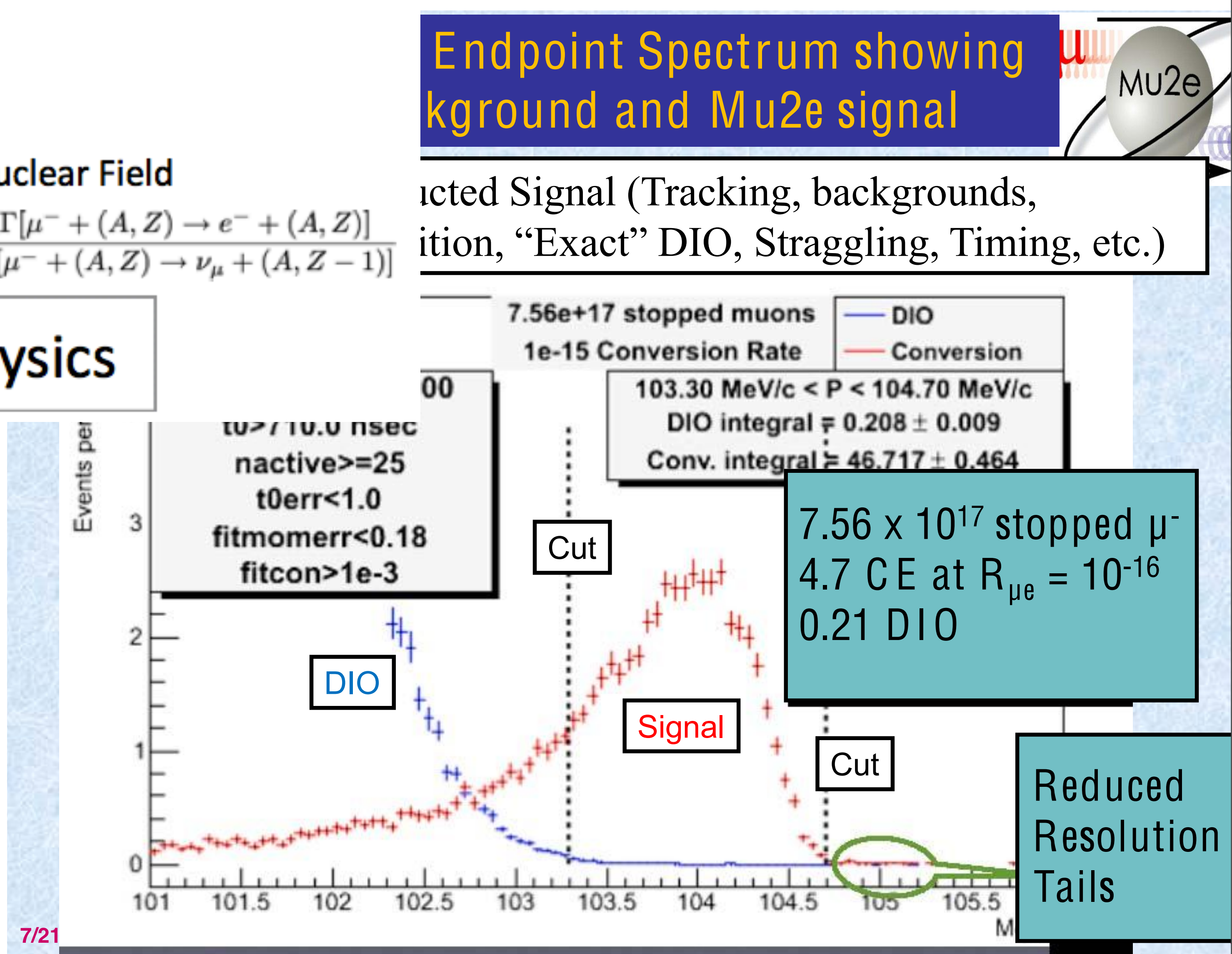
  - MC:DIO = 1:1000(H), 2:1(Si), 13:1(Cu)
  - τ(free μ-) = 2.2 μs
  - τ(μ⁻;Si) = 0.76 μs

- Charged Lepton Flavor Violation (CLFV)

$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$ μ-e Conversion in Nuclear Field

$$\mathrm{BR}[\mu^- + (A,Z) \rightarrow e^- + (A,Z)] \equiv \frac{\Gamma[\mu^- + (A,Z) \rightarrow e^- + (A,Z)]}{\Gamma[\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)]}$$

Clear evidence of the new physics

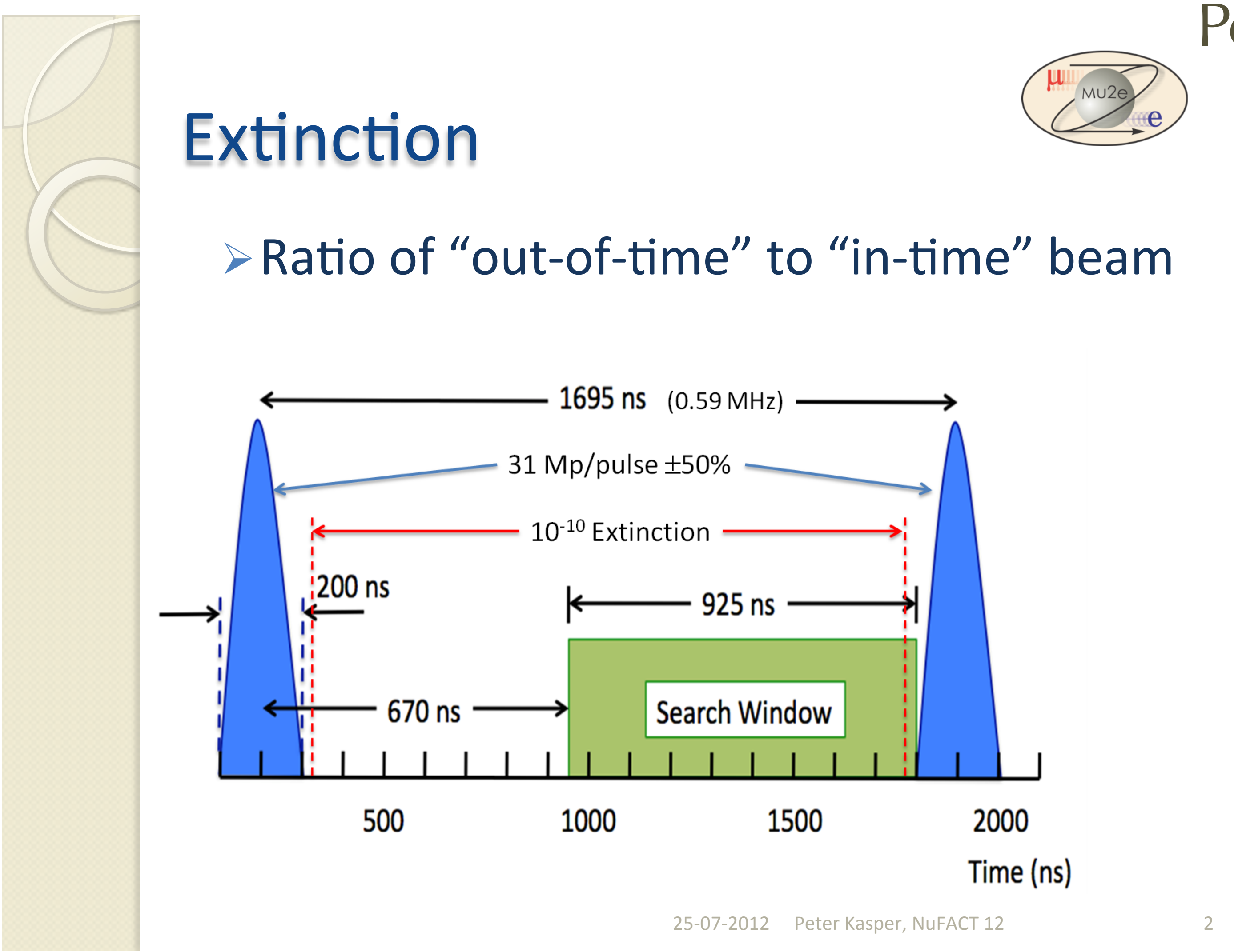


Ed Hungerford

Extinction & beam transport

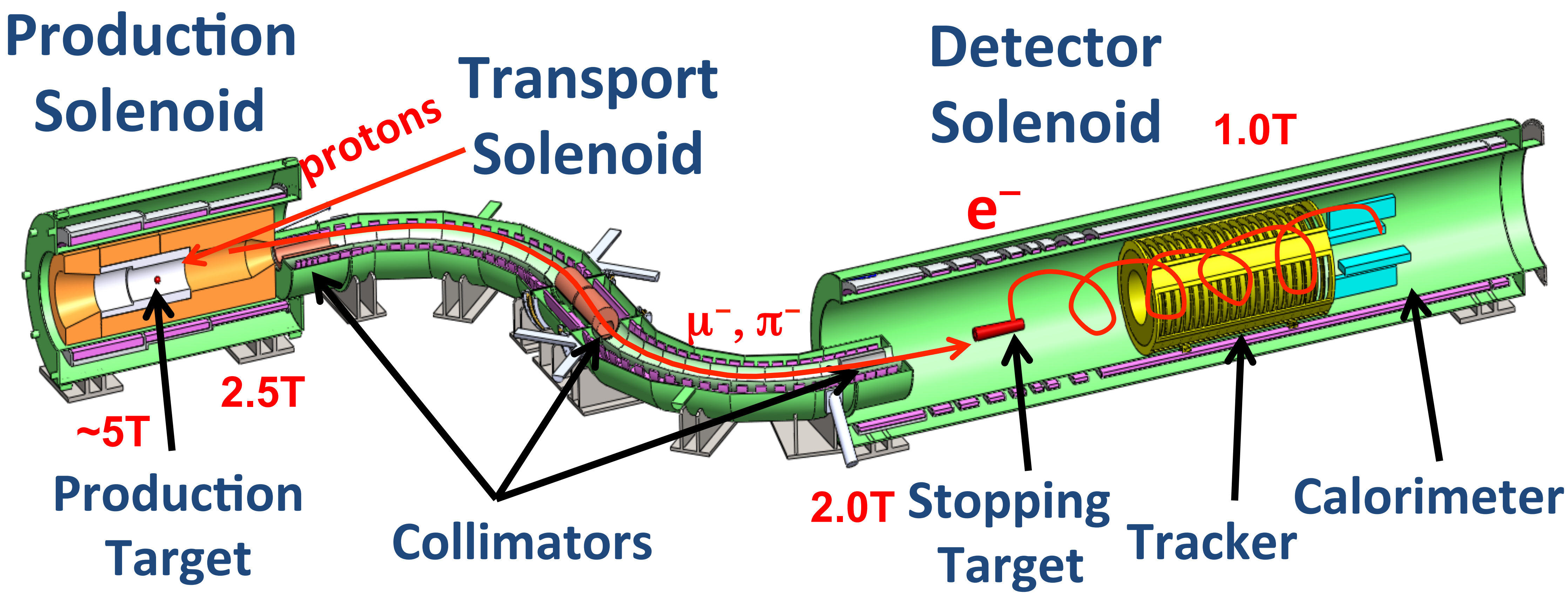
- There is no coincidence as in $\mu \to e\gamma$
- Monochromatic high-energy positron at the end of the spectrum
- Create muons → wait → measure

Peter Kasper



- Need extinction < 10^{-10}

μ2e @ FNAL apparatus



(not shown: Cosmic Ray Veto, Proton Dump, Muon Dump, Proton/Neutron absorbers, Extinction Monitor, Stopping Monitor)

- Beam extinction monitor looks at the generated secondaries → monitor the production target

Two schemes under consideration

Two Schemes Under Consideration

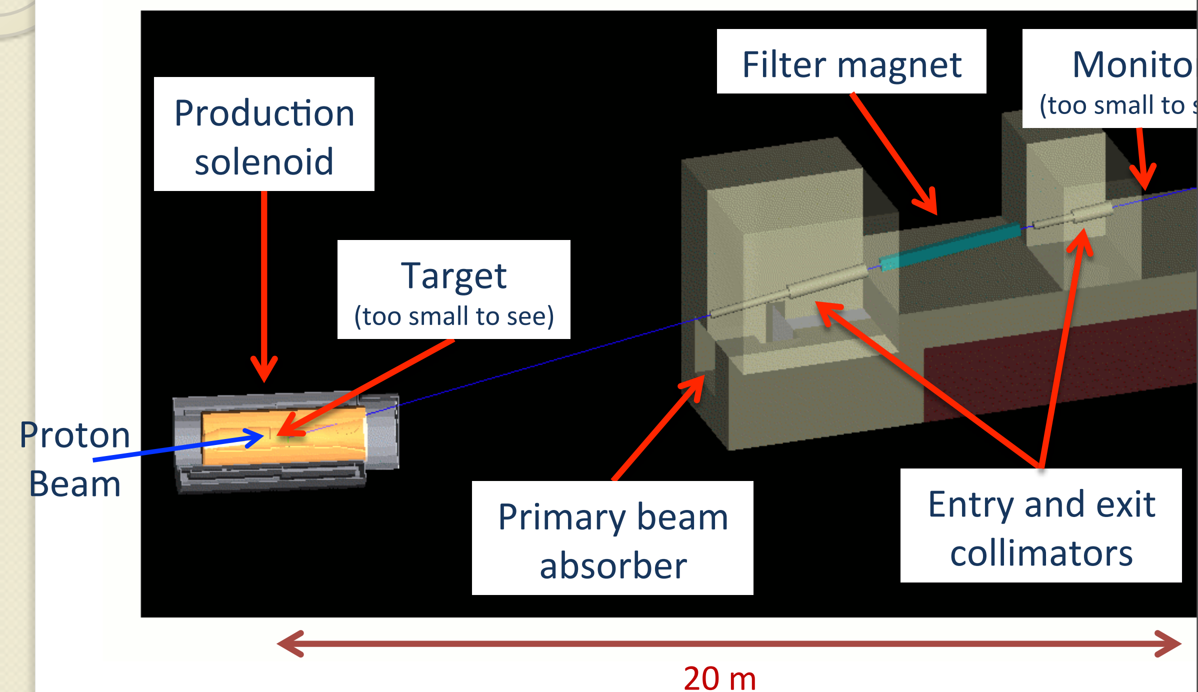
- Pixel Tracker
  - Located above and behind the proton absorber
  - Samples 3 to 4 GeV/c positive charged secondaries
  - Pixel detectors reconstruct and count straight tracks with a well defined direction in 25ns time bins
- Mini Spectrometer
  - Located beside the proton absorber
  - Samples ~ 1 GeV/c positive charged secondaries
  - Magnetic spectrometer with 4 scintillator stations measures dE/dx, time of flight, and momentum of identified particle tracks

25-07-2012 Peter Kasper, NuFACT 12

- Take a decision by the end of the year

Peter Kasper

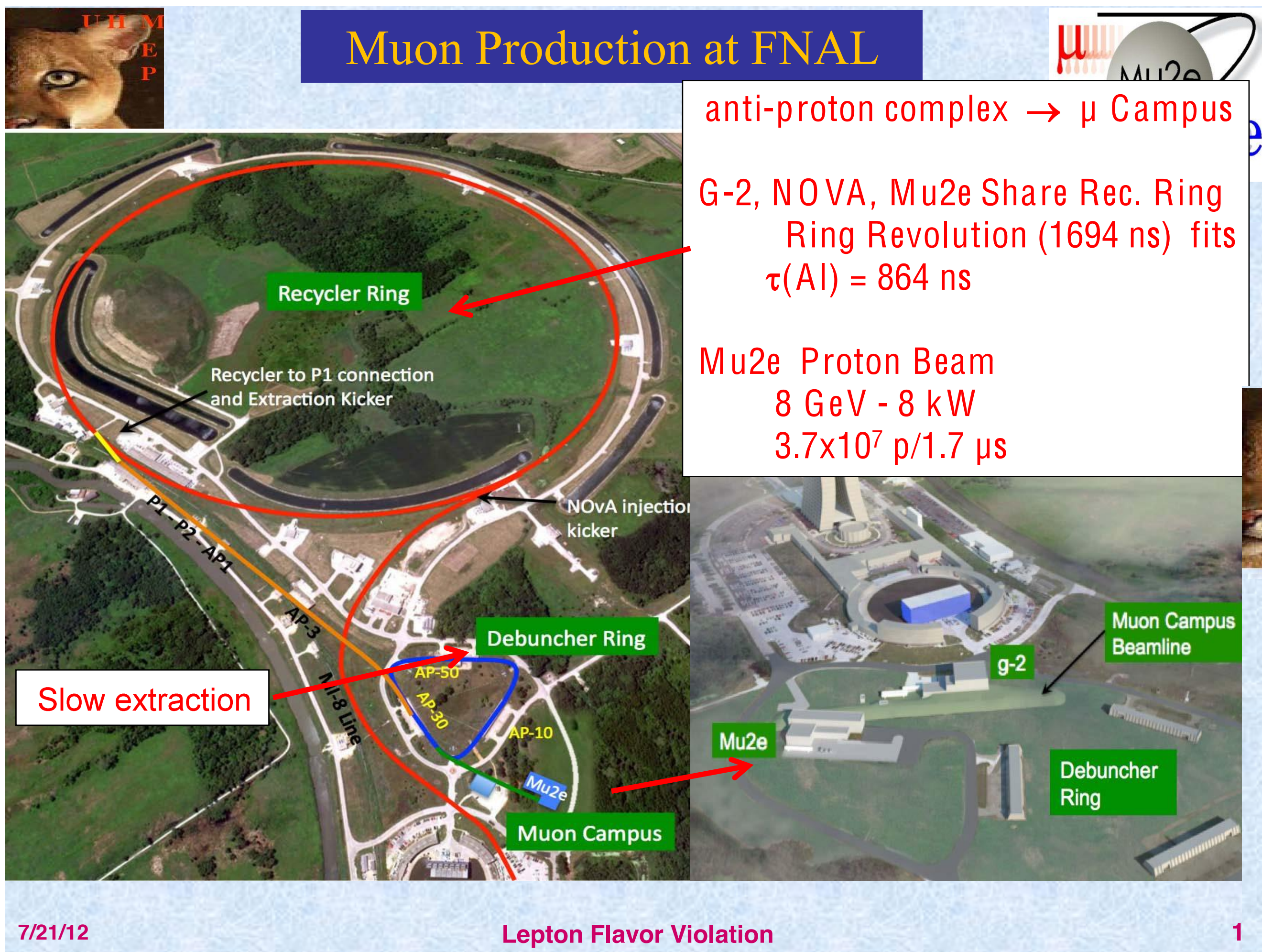
Filter for Pixel Monitor



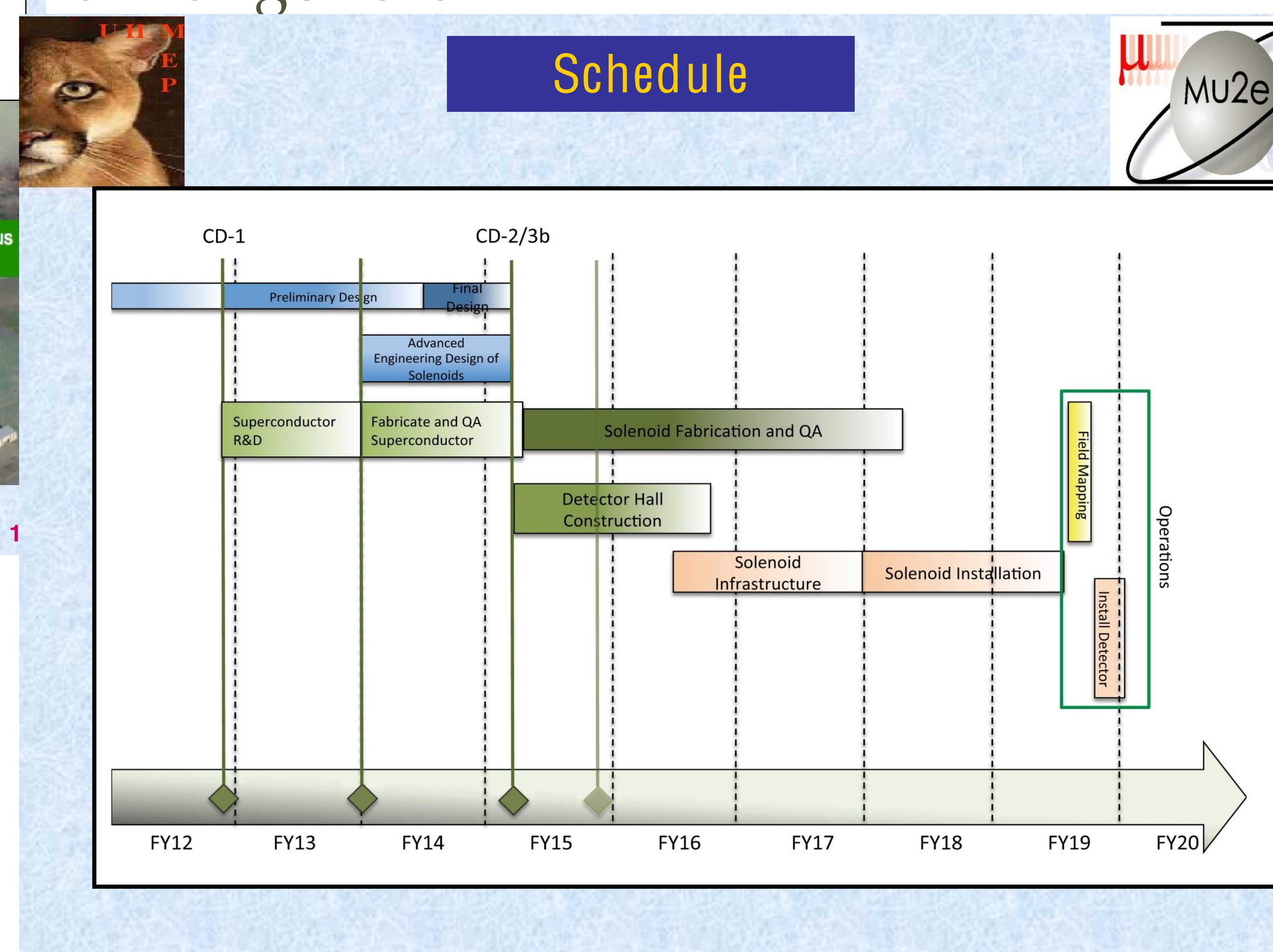
27-07-2012 Peter Kasper, NuFACT 12

μ2e @ FNAL Status

- Antiproton complex → muon campus
- Got CD1 in June 2012!
- Starting in FY2019



Ed Hungerford

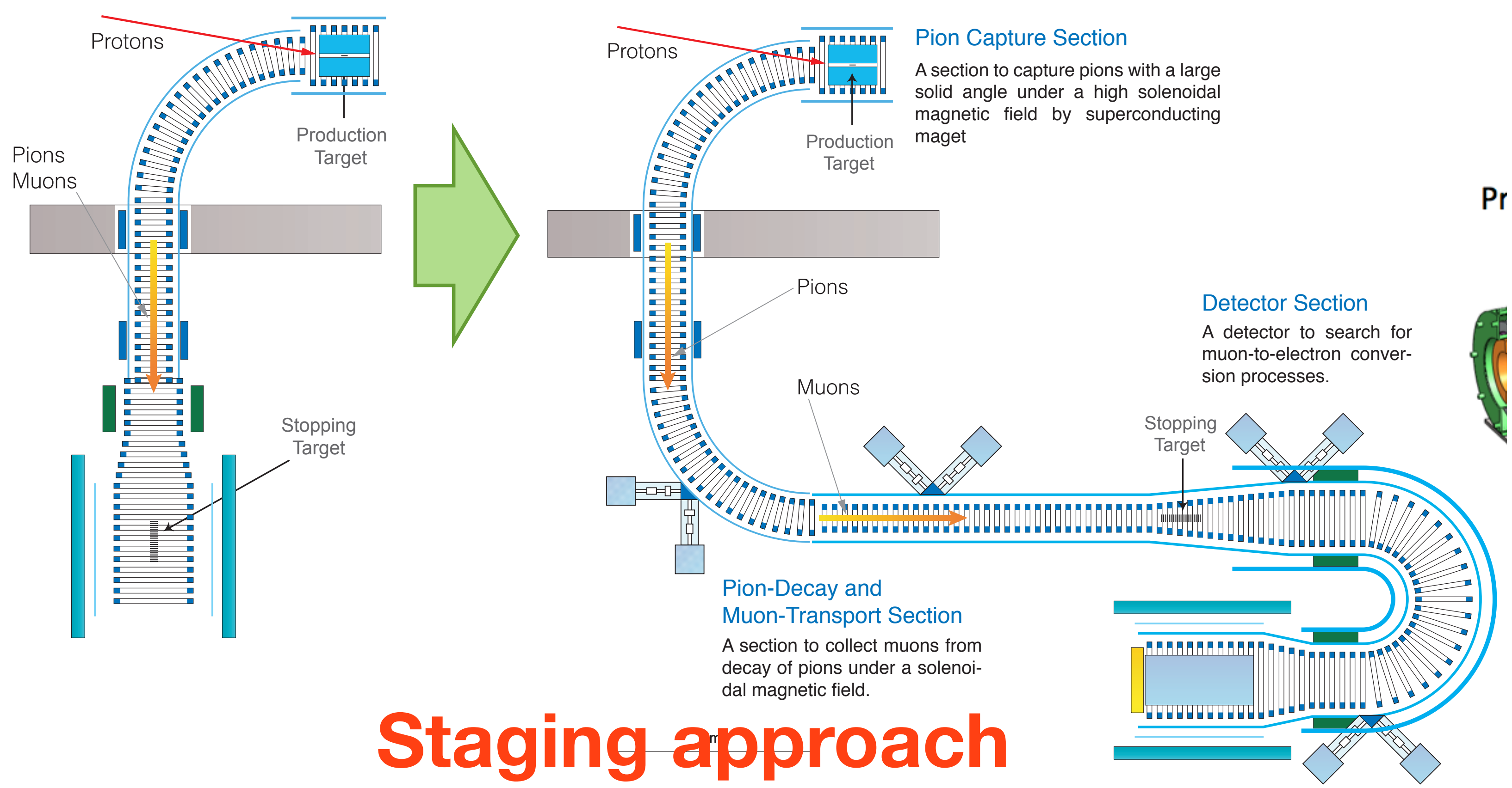


μ2e in Japan → Comet phase I e II

- Strong PAC endorsement in March 2012. Submitted proposal in July 2012
- Start construction in 2013
  - physics measurement + background study

COMET @J-PARC

A. Sato



Staging approach

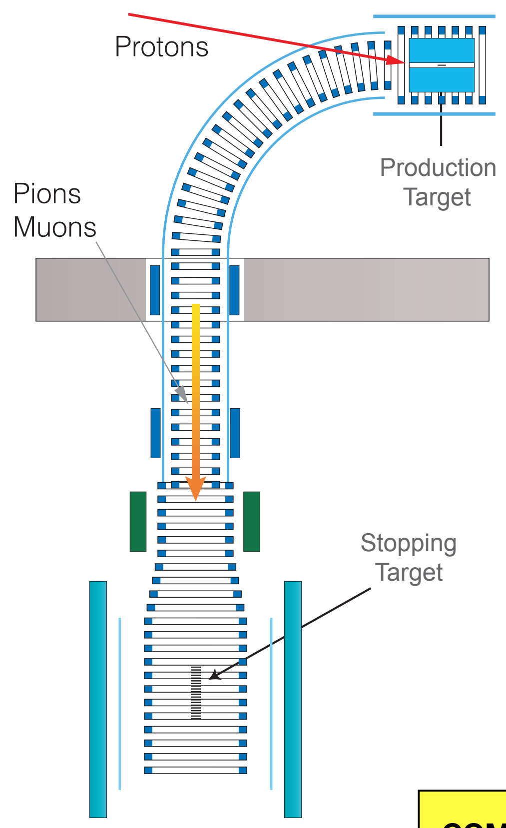
COMET Phase-I :	COMET Phase-II :
physics run 2017-	physics run 2019-
BR(μ+Al→e+Al)<7x10^{-15} @ 90%CL	BR(μ+Al→e+Al)<6x10^{-17} @ 90%CL
*8GeV-3.2kW proton beam, 12 days	*8GeV-56kW proton beam, 2 years
*90deg. bend solenoid, cylindrical detector	*180deg. bend solenoid, bend spectrometer, transverse tracker+calorimeter
*Background study for the phase2	

Status of COMET project

- We have submitted a LOI of a staging plan and ap roposal of Phase-I to the J-PARC PAC.
  - **COMET Phase-I: A proposal has been submitted (July 2012)**
    - $B(\mu+Al \rightarrow e+Al)<7\times10^{-15}$ @ 90%CL
      - 8GeV-3.2kW proton beam, 12 days
      - 90deg. bend solenoid, cylindrical detector
    - Background study for the phase2
  - **COMET Phase-II: Stage-1 approved (2009)**
    - $B(\mu+Al \rightarrow e+Al)<6\times10^{-17}$ @ 90%CL
      - 8GeV-56kW proton beam, 2 years
      - 180deg. bend solenoid, bend spectrometer, transverse tracker+calorimeter
- After a discussion in the last PAC meeting (16-17, March, 2012), We got a strong recommendation from the J-PARC-PAC.
  - "COMET is a high priority component for the J-PARC program." (KEK/J-PARC-PAC March/2012)
  - The IPNS proposed, as the first priority item in the next 5-year plan, to construct a proton beam line and the 1st half of solenoid magnets for COMET Phase-I. The PAC endorsed the laboratory plan.
- **J-PARC plans to submit a budget request to the Ministry of Education, Culture, Sports, Science and Technology, the budget includes 20M-USD(1USD=100JPY) for the COMET-phase1.**
- **The construction will be started from 2013.**

Key Points of COMET(S.E.S 10^{-15})

A. Sato



Intense Pulsed Proton Beam
8GeV-3.2kW (12 days)
width~100ns, separation>1μs
Extinction level < 10^9 **reduce beam related BG**

Pion Capture Solenoid
5T superconducting **10^{11} μ^-/sec**

Long Transport Solenoid
L >10m
Curved 90deg Solenoid **eliminate energetic μ (>75 MeV/c) and pions**

Thin Stopping Target
Al 200μm x 17 **improve e^- energy resolution**

Electron Spectrometer
Curved Solenoid

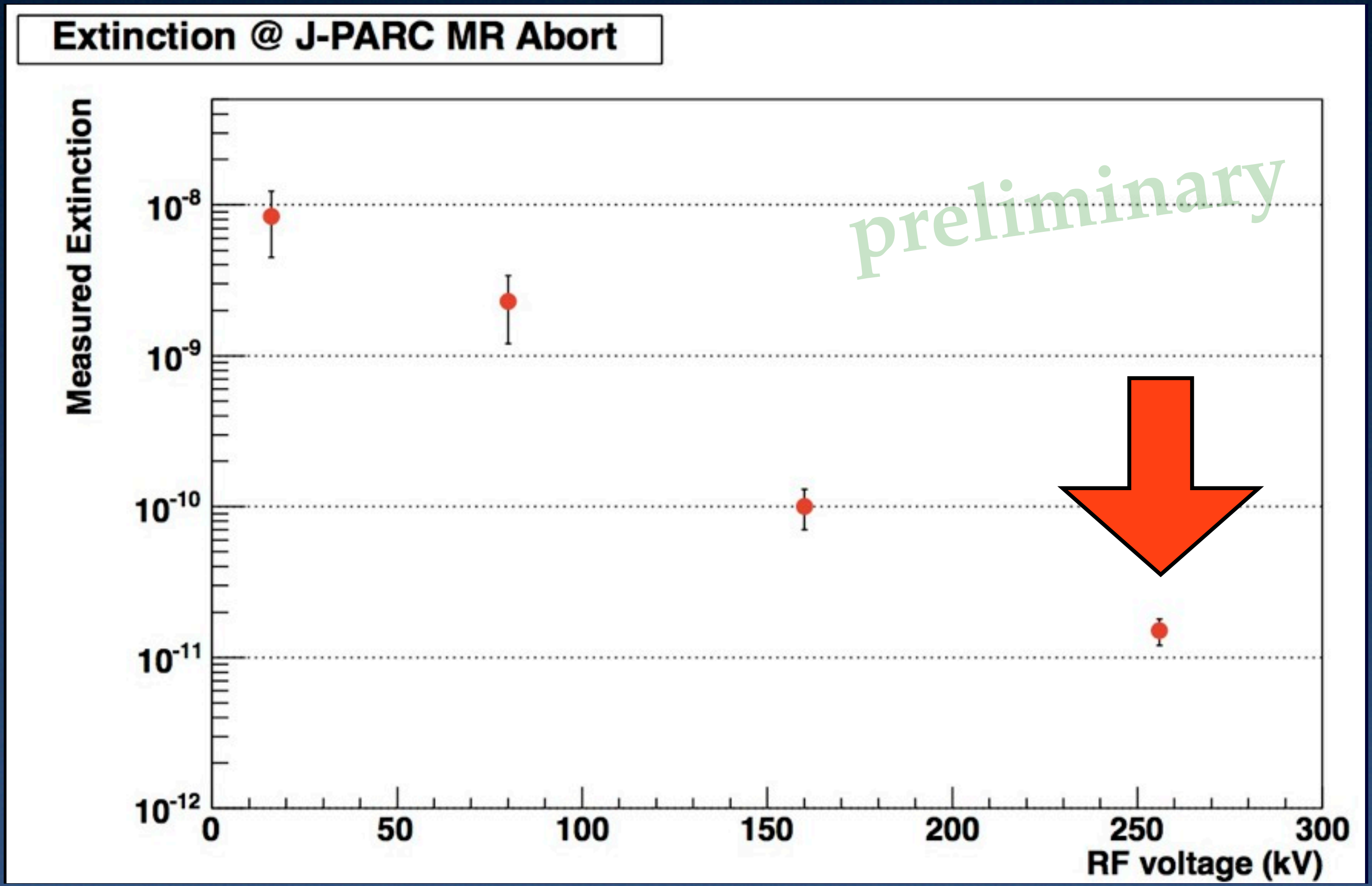
Low-mass Tracker
Cylindrical drift chamber

COMET Phase-I :
physics run 2017-
BR(μ+Al→e+Al)<7x10^{-15} @ 90%CL
*8GeV-3.2kW proton beam, 12 days
*90deg. bend solenoid, cylindrical detector
*Background study for the phase2

Goal of COMET Phase-I

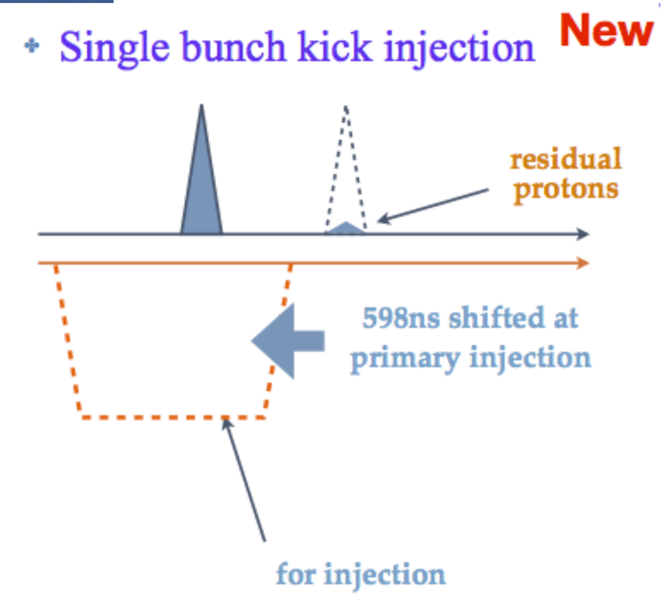
- **Background Study for COMET Phase-II**
  - direct measurement of potential background sources for the full COMET experiment by using the actual COMET beamline constructed at Phase-I
- **Search for μ-e conversion**
  - a search for μ^-–e^- conversion at intermediate sensitivity which would be more than 100 times better than the SINDRUM-II limit

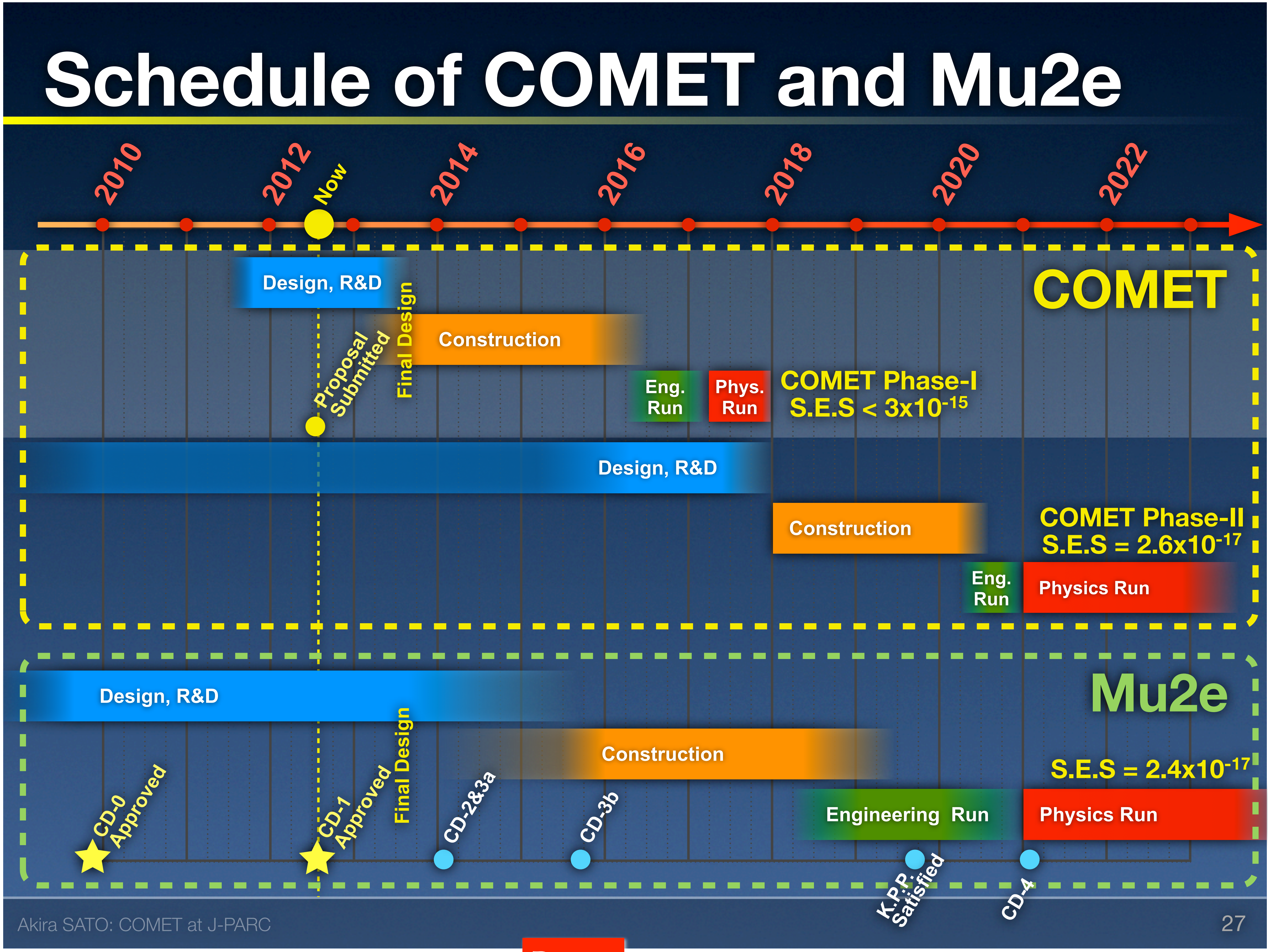
Results of Extinction Measurement (June, 2012)



A. Sato

- proton extinction factor of 1.5 x10^{-11} has been achieved.
  - at MR abort line after acceleration up to 30GeV.
- Next step: measurements at SX line.





Schedule of COMET and Mu2e
2010
2012
Now
2014
2016
2018
2020
2022
COMET
Design, R&D
Proposal Submitted
Final Design
Construction
Eng. Run
Phys. Run
COMET Phase-I
S.E.S < 3x10-15
Design, R&D
Construction
COMET Phase-II
S.E.S = 2.6x10-17
Eng. Run
Physics Run
Mu2e
Design, R&D
Final Design
Construction
S.E.S = 2.4x10-17
CD-0 Approved
CD-1 Approved
CD-2&3a
CD-3b
Engineering Run
Physics Run
K.P.P. Satisfied
CD-4
Akira SATO: COMET at J-PARC
27

Deeme

A. Sato

Status update
Extinction measurement solution (FNAL)
The results of the extinction measurements

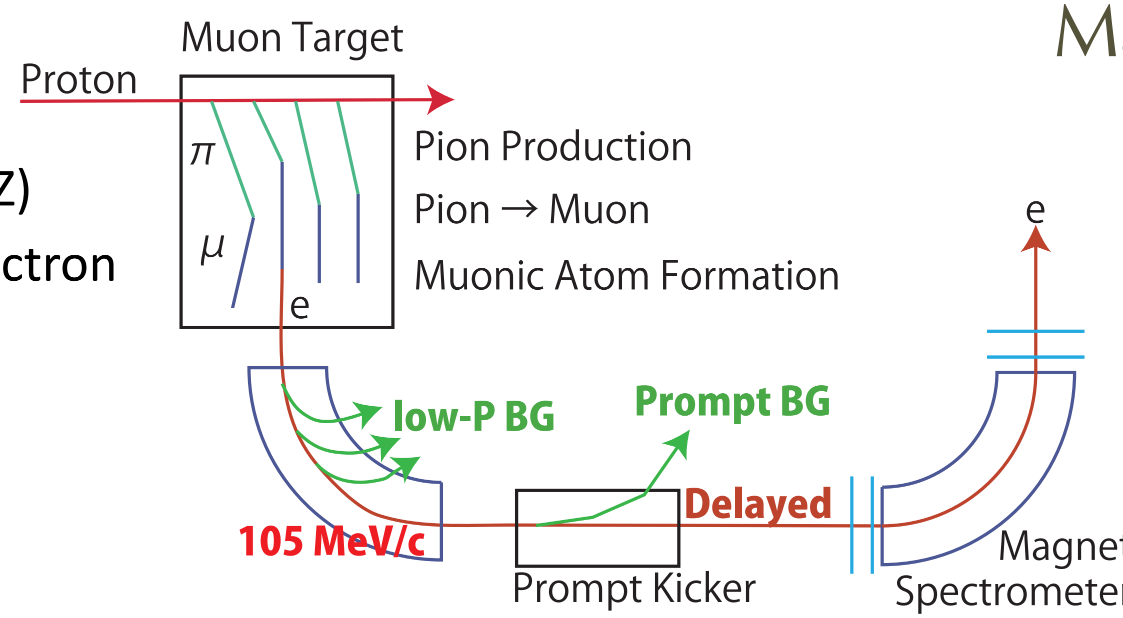
μ→e in the meanwhile: DeeMe

- Deeme search for μ2e @J-Parc with a 10^{-14} sensitivity in 2015
  - Stage 1 approved in 2011
- Production target is also the conversion target (SiC to have high-Z material)
  - j-Parc H-beam line

DeeMe(P41)

Masa Aoki

- Process : $\mu^- + (A,Z) \rightarrow e^- + (A,Z)$
  - A single mono-energetic electron
    - 105 MeV
    - Delayed：~1μS
- No accidental backgrounds
- Physics backgrounds
  - Muon Decay in Orbit (DIO)
    - $E_e > 102.5$ MeV (BR:10^{-14})
    - $E_e > 103.5$ MeV (BR:10^{-16})
  - Beam Pion Capture
    - $\pi^- + (A,Z) \rightarrow (A,Z-1)^* \rightarrow \gamma + (A,Z-1)$
      $\gamma \rightarrow e^+ e^-$
    - Prompt timing



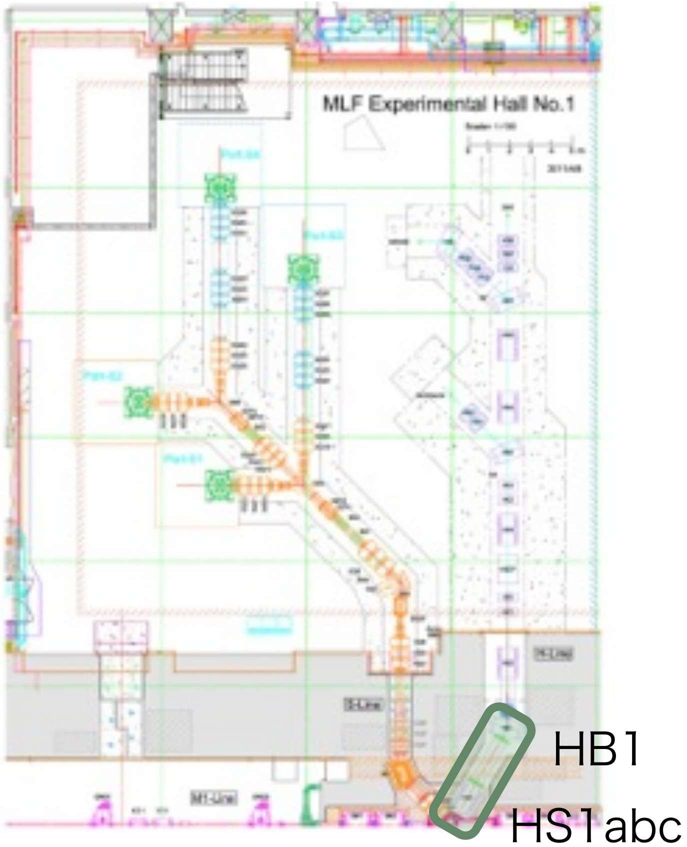
- Low Energy main part: suppressed by the beamline.
- High Energy tail: Magnet Spectrometer (Δp < 0.3%)

- Main pulse: Kicker to reduce the detector rate.
- after-protons: Suppressed owing to the extremely small after-protons from RCS -- $R_{AP} < 10^{-17}$.

H-line Construction Status

H-line is multipurpose beamline

- DeeMe
- g-2/EDM
- muonium HFS
- μCF and other muon programs



Front-end magnets are already fabricated.

SiC Rotating Target

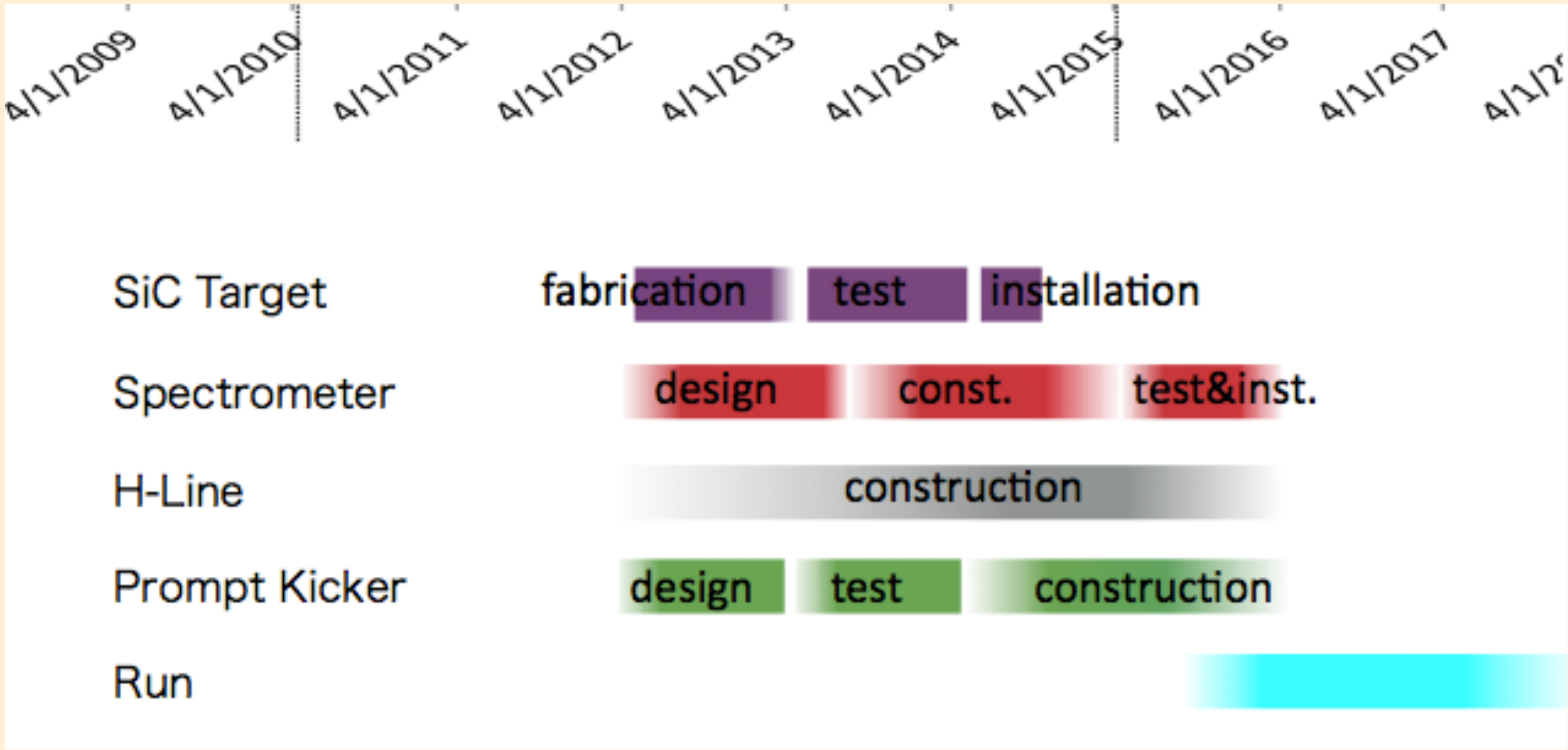
- Extremely important to increase the physics sensitivity:
  - $f_C \times f_{MC}$ = 0.08(C), 0.46(SiC).
  - proton loss: 5% → ~10%
    Discussion with neutron group is ongoing
- Development of a graphite rotating target has almost completed. It will be installed in the summer 2013.
- Build another one with SiC fins instead of graphite fins; planning to install in 2014.

graphite fins

rotating target module

Question for DeeMe:

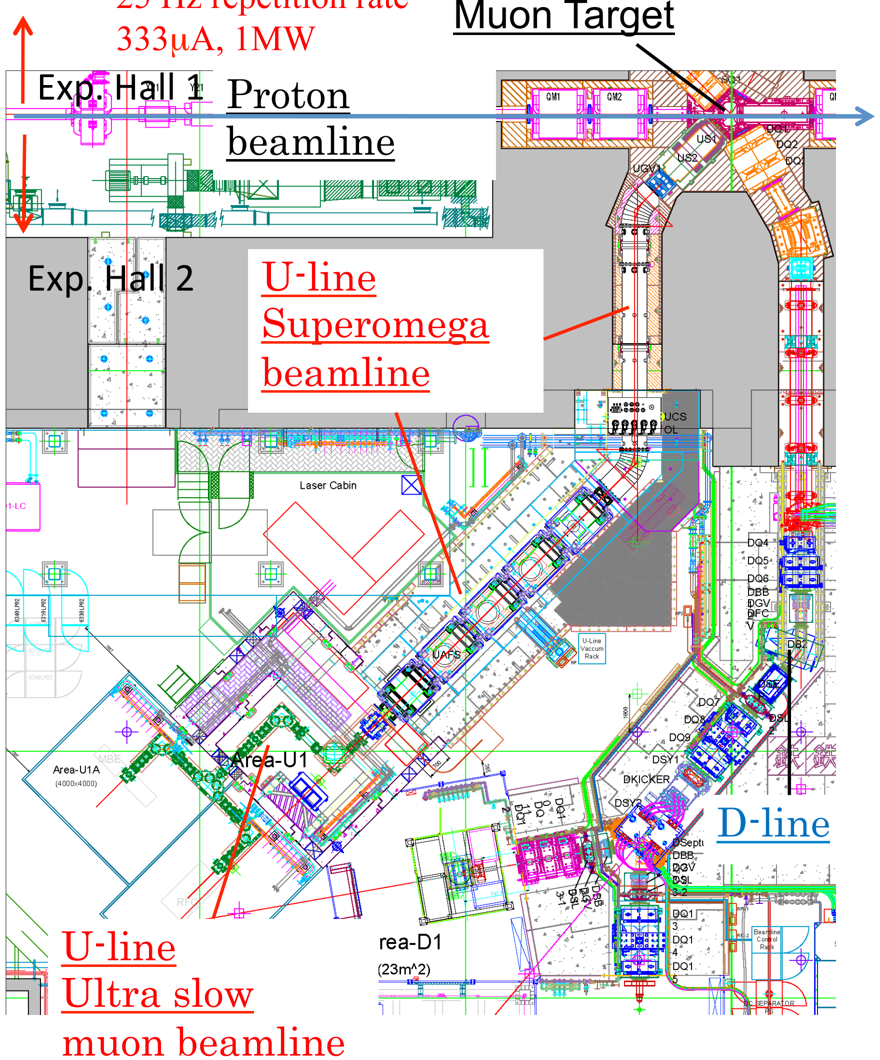
Keep us up-to-date with the schedule



J-parc muon facilities

- U-beam line is under construction
  - Curved solenoid tested and installed

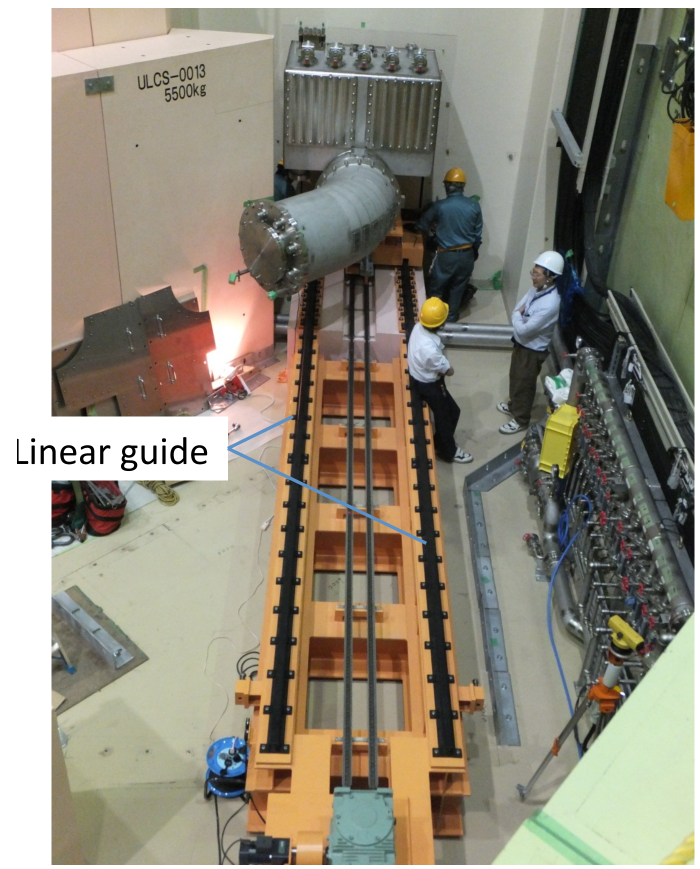
Yutaka Ikedo



Superomega beamline

- The second muon beamline under construction on U-line in MLF/J-PARC.
- First aim of Superomega is surface muon source for Ultra Slow muon beam with high intensity and high luminosity.
  - ➢ D-line: In operation.
    Decay and surface muon.
    Intensity: $1 \times 10^7\ \mu^+/s$
  - ➢ U-line: Under construction.
    Superomega beamline.
    Design to capture and transport muons up to 45 MeV/c.

ed solenoid

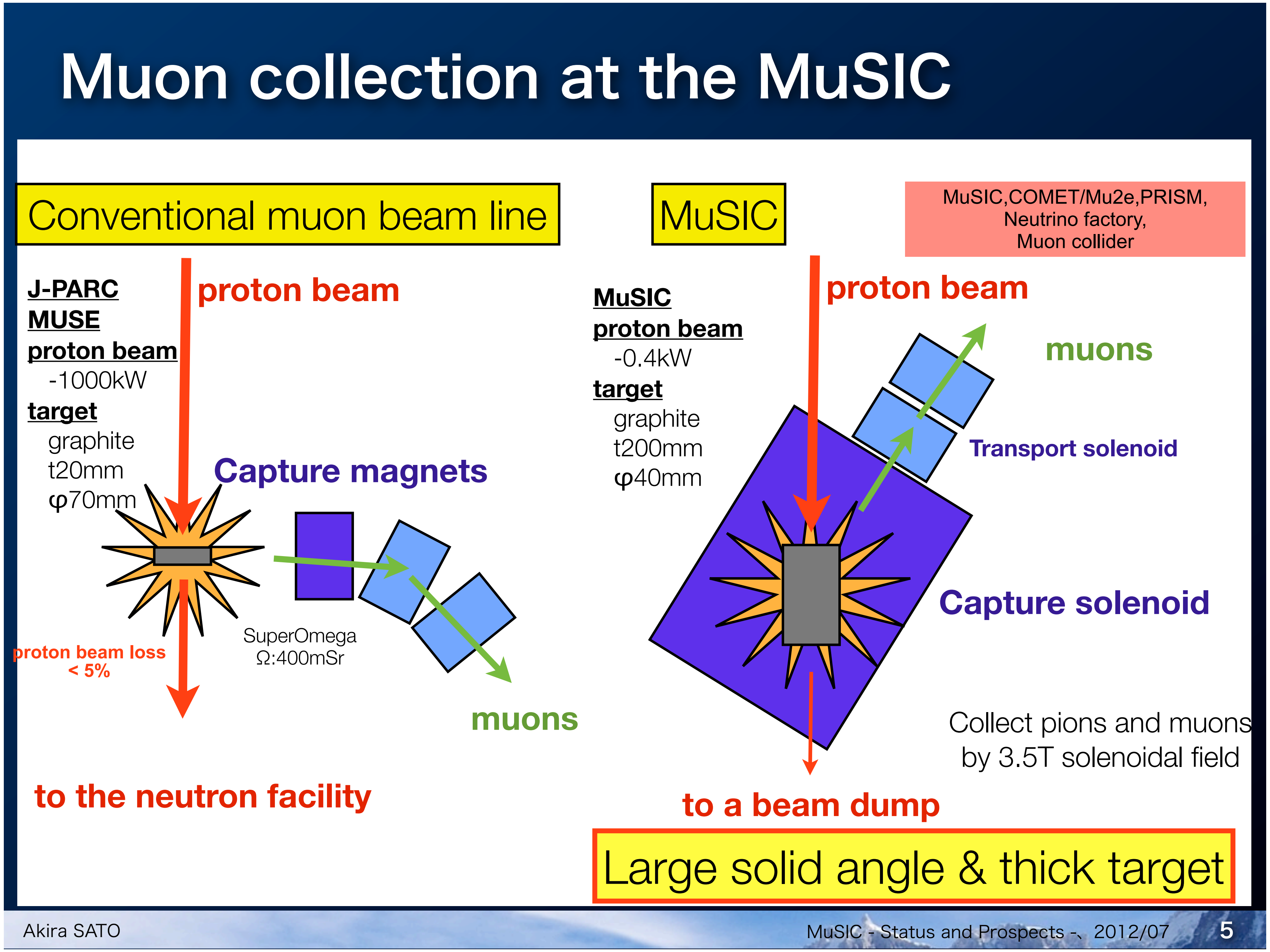


- Curved solenoid is placed on the trolley with radiation shields.
- And linearly inserted into U-line tunnel on the linear guide.

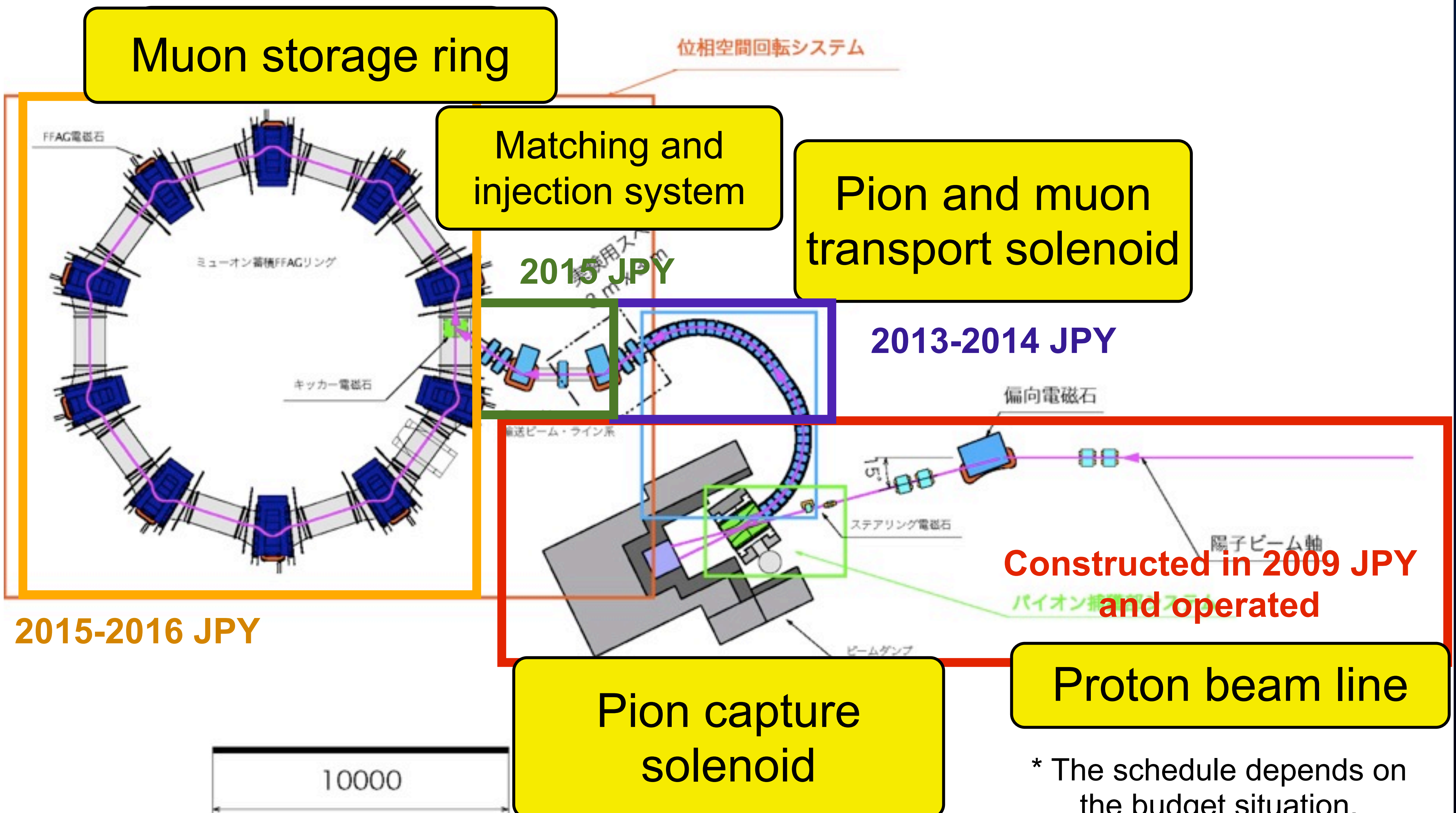
Novel beam lines

- MuSIC at Osaka University
- Produce $10^{8\div9}$ μ/sec with only 400W p-beam

Akira Sato



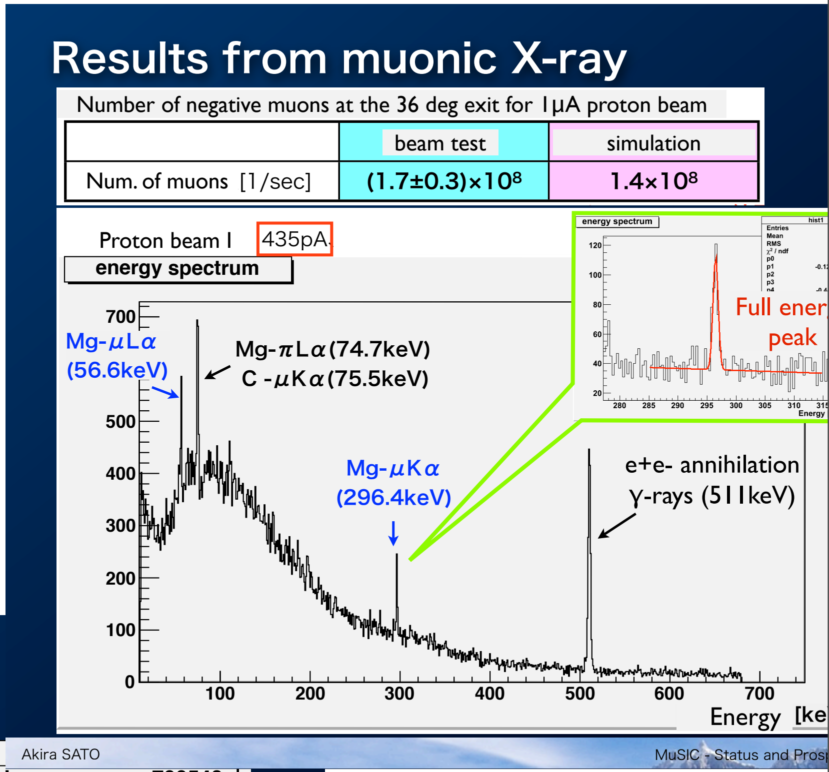
Schedule

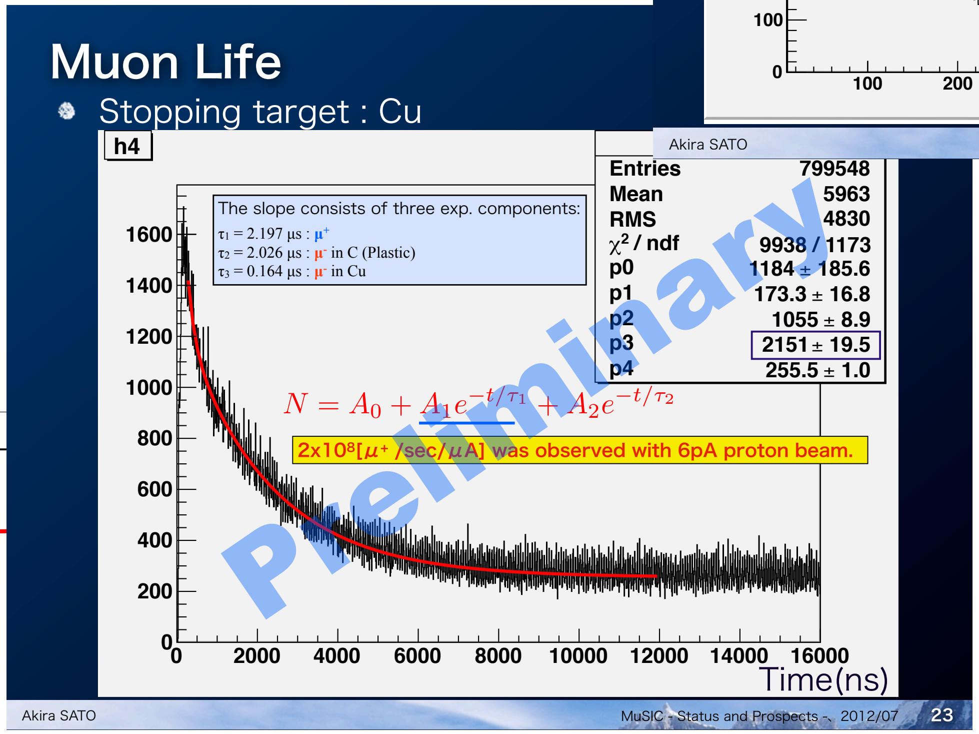


* The schedule depends on the budget situation.

7

- Measured the # of muons from target. At low p-current.
  - muonic x-rays
  - muon lifetime (capture in Copper)
- Extrapolate at high proton beam
  - can the target survive? Yes!

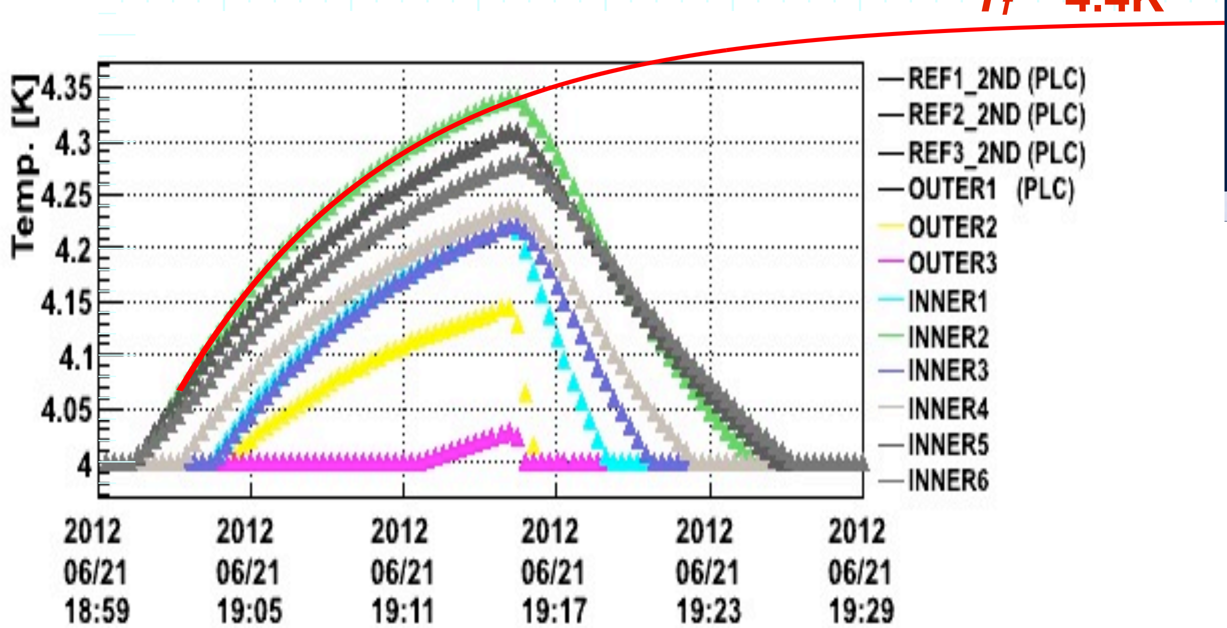




Terminal Temperature

$T = T_0 + (T_f - T_0)(1 -$

T_f ~ 4.4K



The coil temperature up to ~6.5K is acceptable.
MuSIC can work with 400W proton beam.

Akira Sato

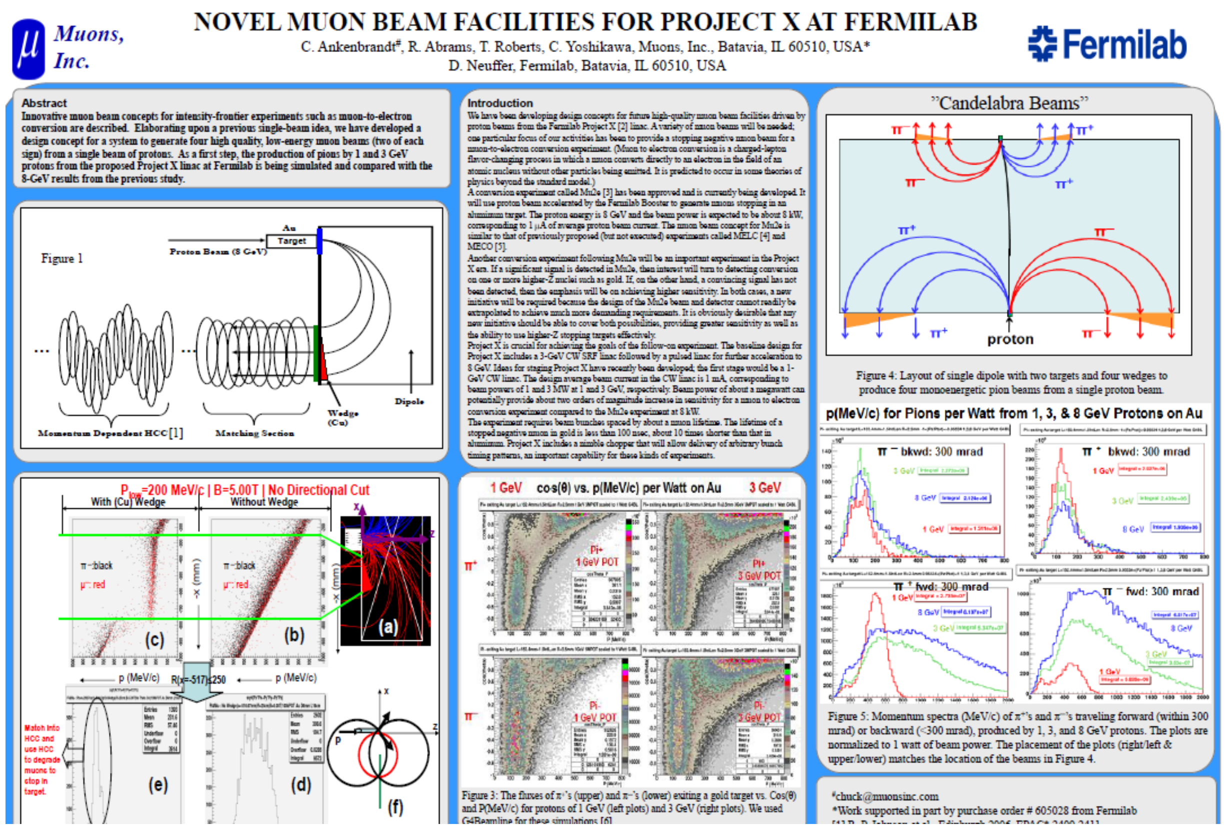
Question for MUSIC:

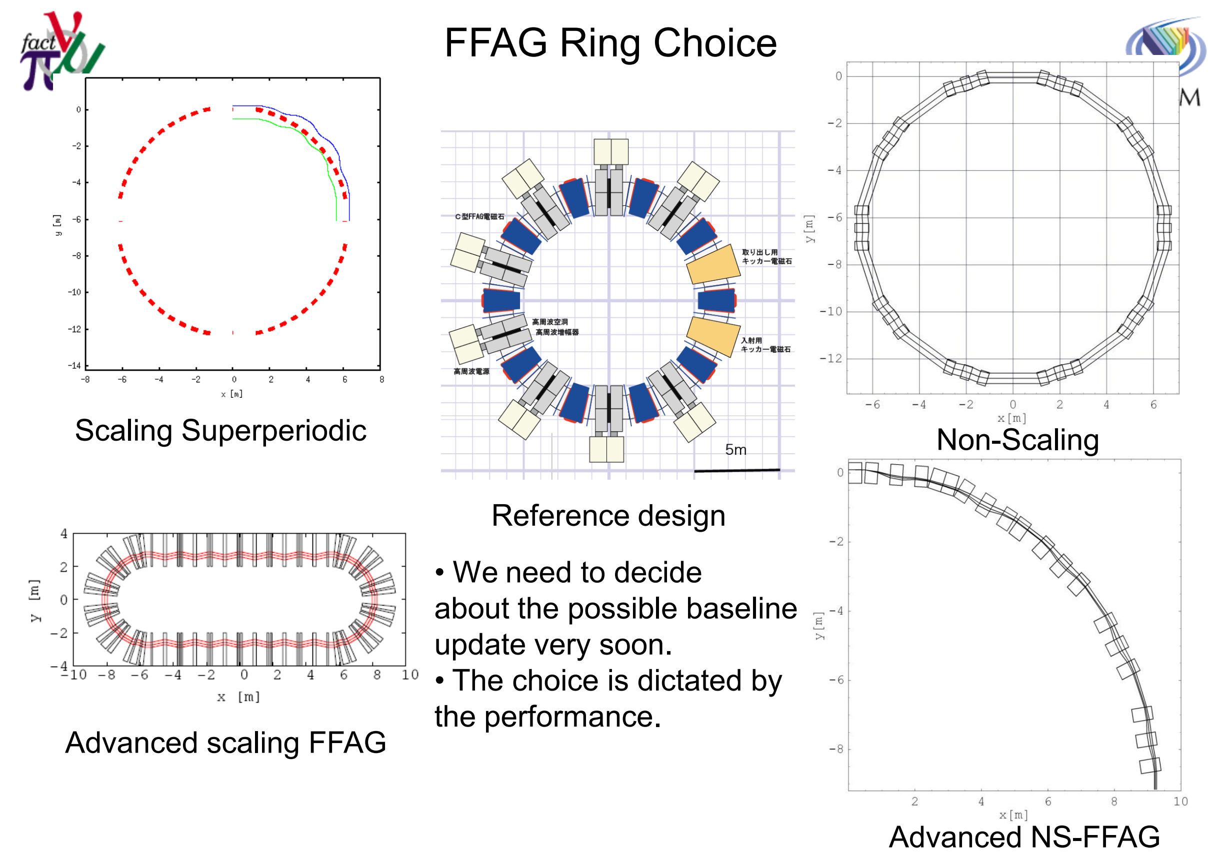
Which is the spectrum
Which is the rate as a function of p
Which is the polarization
Possible experiments in the beamline
Pion and Muon transport solenoid status

The Future

- Project-X, PRISM/PRIME
  - μ2e to 3×10^{-19}
  - to have more muons → forward capture and cool
  - at the limit of technology for B intensity, radiation etc...

See WG3+4 joint session talks



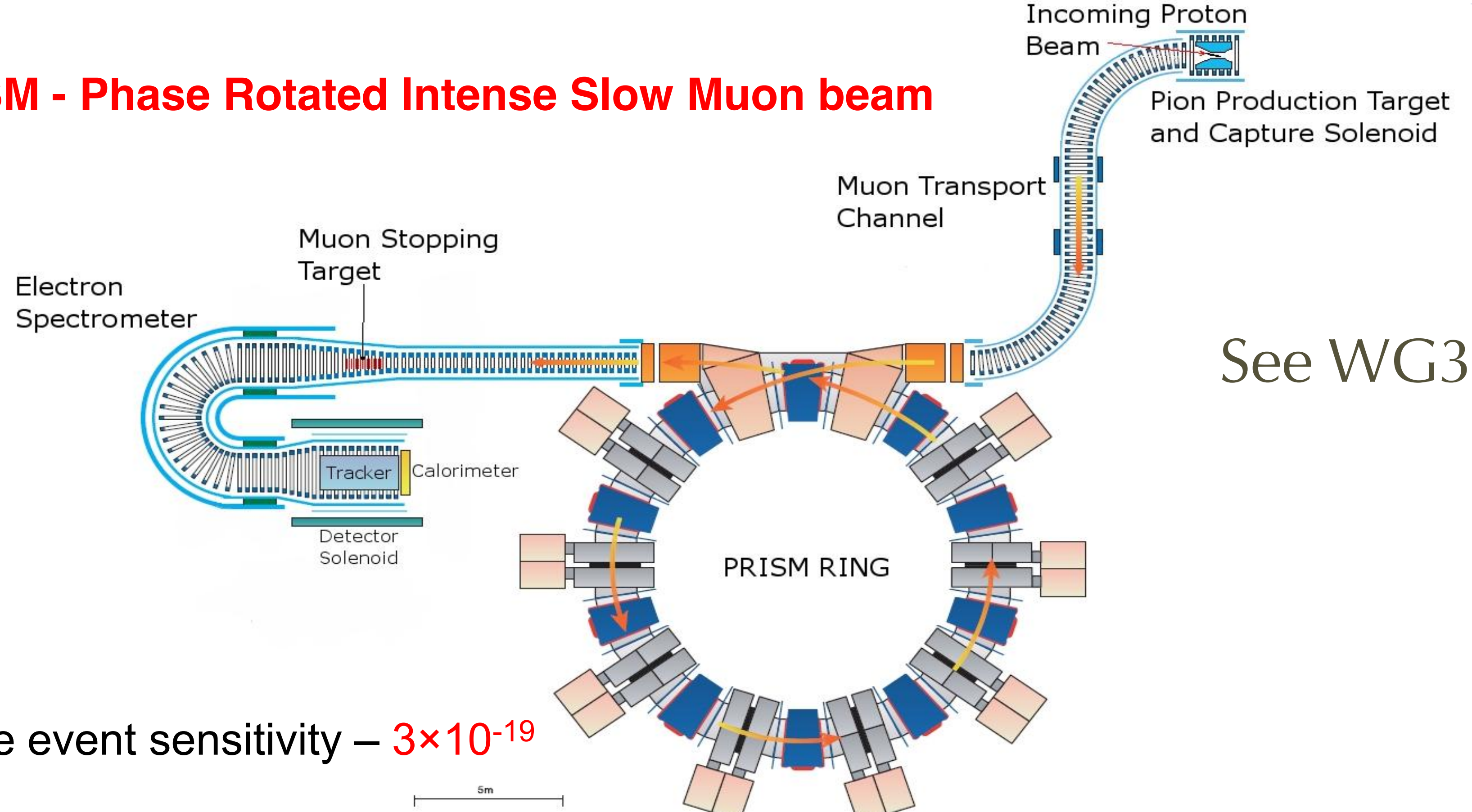


J. Pasternak

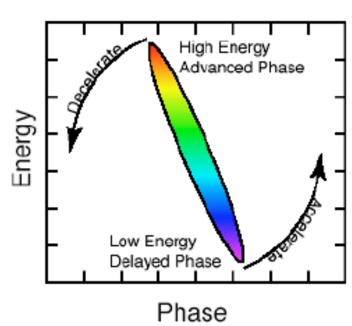
C. Ankenbrandt, V. Blackmore, J. Pasternak, T. Luo...

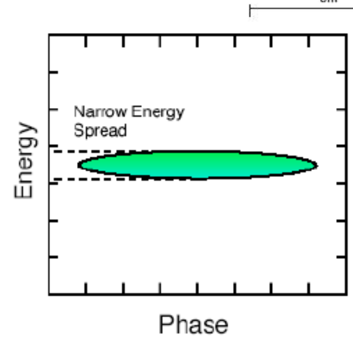
Layout of the PRISM/PRIME

PRISM - Phase Rotated Intense Slow Muon beam



Single event sensitivity – 3×10^{-19}





The PRISM/PRIME experiment based on FFAG ring was proposed (Y. Kuno, Y. Mori) for a next generation cLFV searches in order to:

- reduce the muon beam energy spread by phase rotation,
- purify the muon beam in the storage ring.

J. Pasternak

See WG3+4 joint session talks

Questions to NUFACT 2013

- PSI
  - MEG New results & Upgrade
  - $\mu \to eee$
- μ-e conversion
  - Mu2e
  - COMET Phase I & II
  - DeeMe
- J-PARC MUSE activities : H-Line
  - Mu HFS
  - ultracold-μ production
  - g-2/EDM
- FNAL g-2
- τ-sector
  - combined Belle and BaBar results
  - Prospects for Belle-II and SuperB
- Precision tests
  - cross sections (MuSUN)
  - news on proton radius
- R&D of intense muon source
  - MuSIC
  - J-PARC Beam lines
  - Muon production
  - Muon collection / Cooling (MICE...)
  - Work towards muon collider
- p-EDM
- Beyond
  - Project-X
  - PRISM/PRIME
- Theory
  - Reflect LHC results
    - Higgs
    - Supersymmetry
  - Neutrino oscillation parameters
    - ϑ_{13}
    - δ_{CP}

Thanks

- The Organizers
- All WG4 participants for the fruitful discussions
- My co-conveners