Search for the μEDM at low γ?

- Motivation
- Frozen spin technique
- High and low γ
- A compact storage ring experiment?

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Theoretical expectations for the muon's electric dipole moment

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3. Theoretical expectations from the muon's MDM

The muon's EDM and anomalous MDM are defined through [1]

$$\mathcal{L}_{\text{EDM}} = -\frac{i}{2} d_\mu^{\text{NP}} \bar{\mu} \sigma^{mn} \gamma_5 \mu F_{mn}, \tag{8}$$

$$\mathcal{L}_{\text{MDM}} = a_\mu^{\text{NP}} \frac{e}{4m_\mu} \bar{\mu} \sigma^{mn} \mu F_{mn}, \tag{9}$$

where $\sigma^{mn} = \frac{i}{2}[\gamma^m, \gamma^n]$ and F is the electromagnetic field strength. These operators are closely related. In the absence of all other considerations, one might expect their coefficients to be of the same order. Parameterizing them as $d_\mu^{\text{NP}}/2 = \text{Im}\, A$ and $a_\mu^{\text{NP}} e/(4m_\mu) = \text{Re}\, A$ with $A \equiv |A| e^{i\phi_{\text{CP}}}$, one finds

$$d_\mu^{\text{NP}} = 4.0 \times 10^{-22}\, e\,\text{cm} \frac{a_\mu^{\text{NP}}}{43 \times 10^{-10}} \tan\phi_{\text{CP}}. \tag{10}$$

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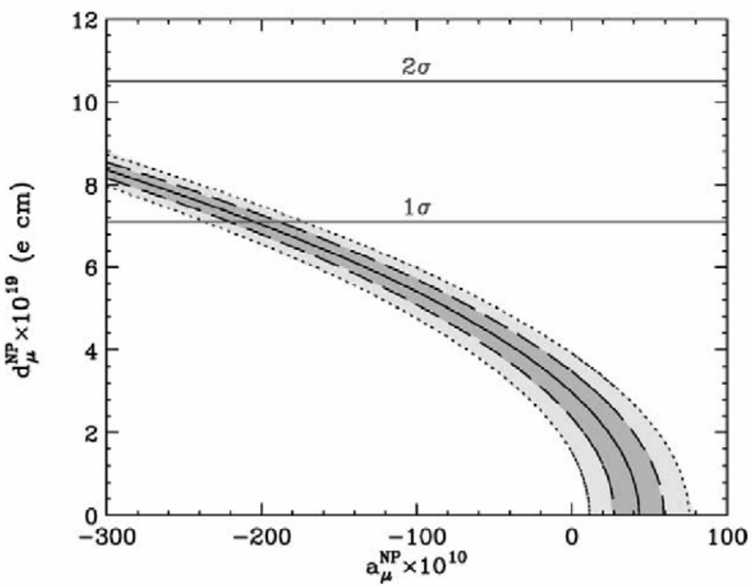

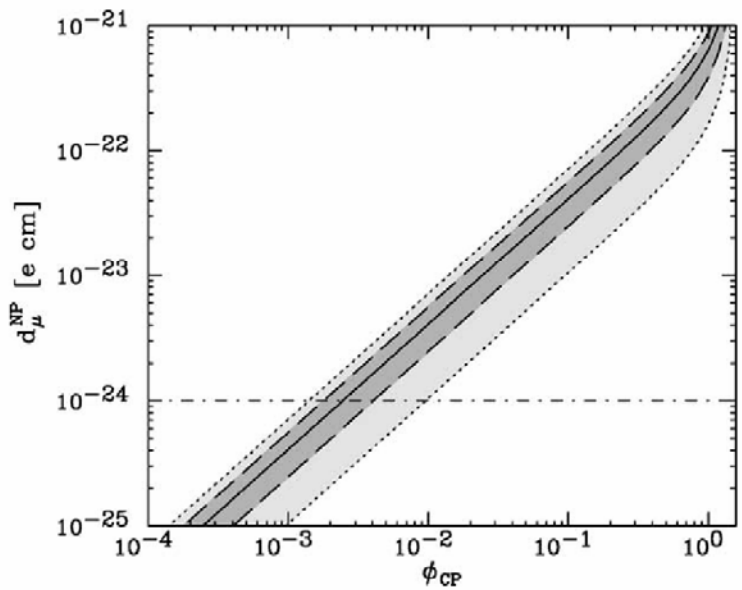

VOLUME 93, NUMBER 5 PHYSICAL REVIEW LETTERS week ending 30 JULY 2004

New Method of Measuring Electric Dipole Moments in Storage Rings

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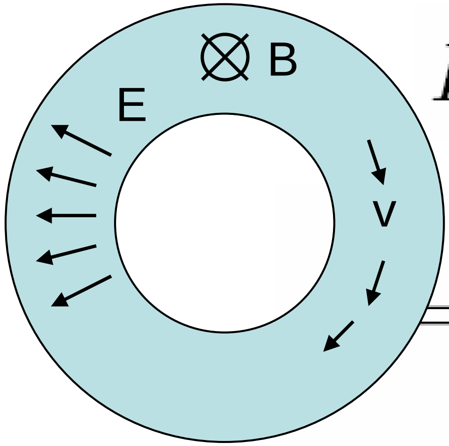
(Received 29 July 2003; published 27 July 2004)

A new highly sensitive method of looking for electric dipole moments of charged particles in storage rings is described. The major systematic errors inherent in the method are addressed and ways to minimize them are suggested. It seems possible to measure the muon EDM to levels that test speculative theories beyond the standard model.

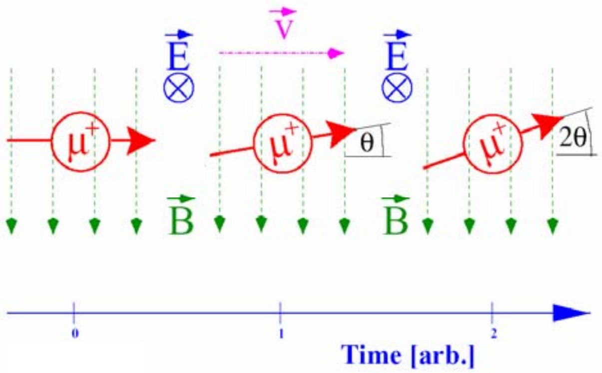
$$\vec{\omega}_e = \frac{\eta}{2}\frac{e}{m}\vec{\beta} \times \vec{B}$$

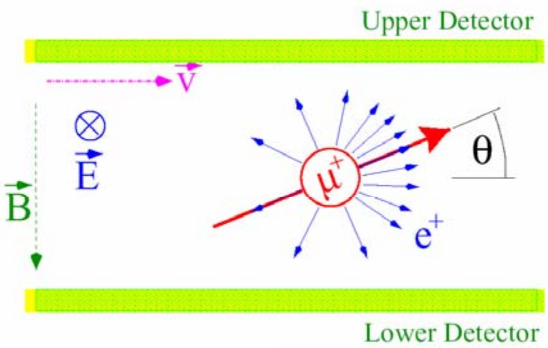
$$\vec{\omega}_a = \frac{e}{m}\left[a\vec{B} + \left(\frac{1}{\beta^2\gamma^2} - \cancel{a}\right)\vec{\beta} \times \vec{E}/c \right]$$



$E \approx$

$= \frac{\ }{\gamma\gamma}$





JPARC LOI

K. Kirch

$$E \approx aBc\beta\gamma^2$$

$$\sigma_\eta = \frac{\sqrt{2}}{\gamma\tau(e/m)\beta BAP\sqrt{N}}$$

$$\sigma_\eta = \frac{\sqrt{2}ac\gamma}{\tau(e/m)EAP\sqrt{N}}$$

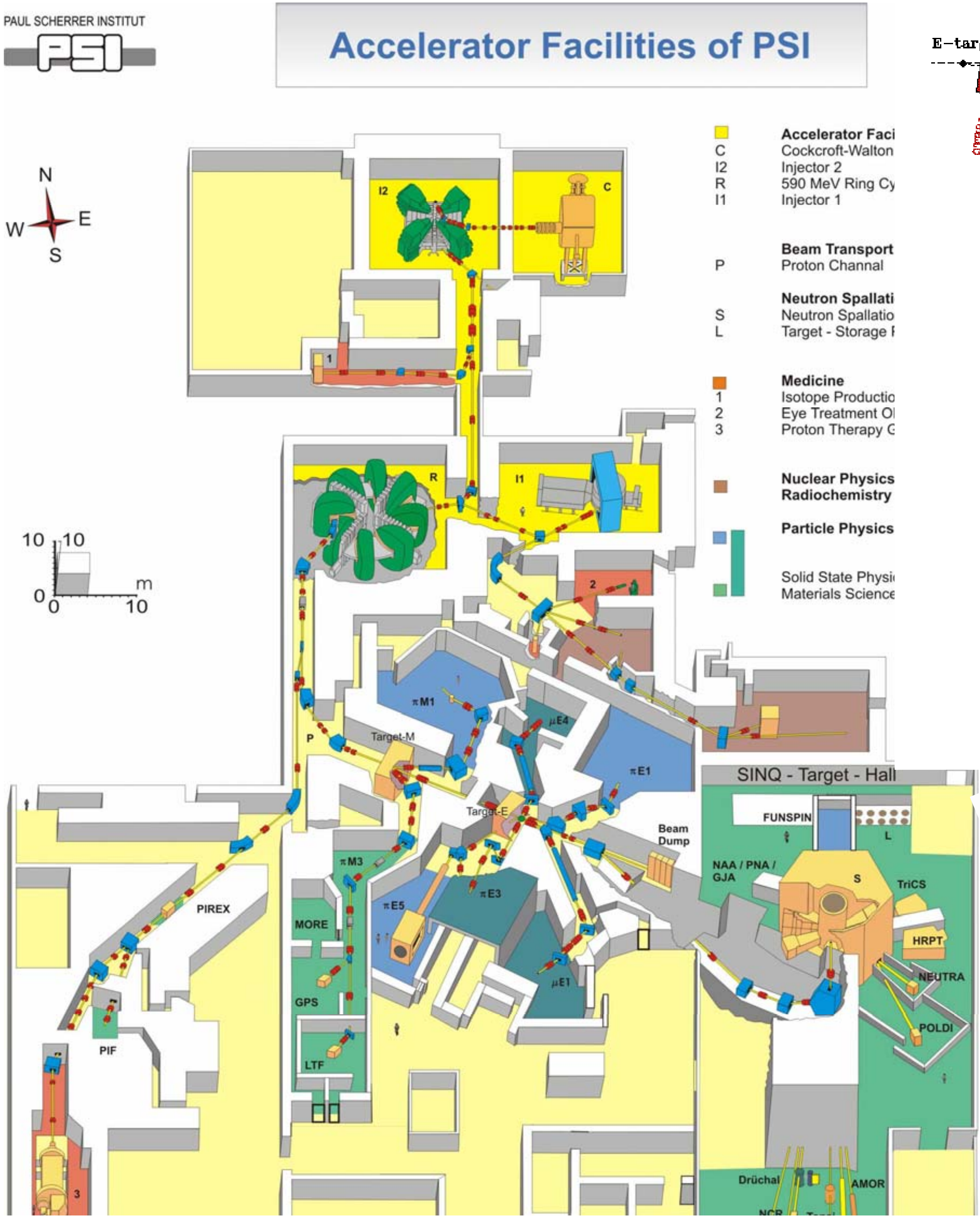
E=2.2MV/m, B=0.25T,
γ=5, R=7m, A=0.3, P=0.5

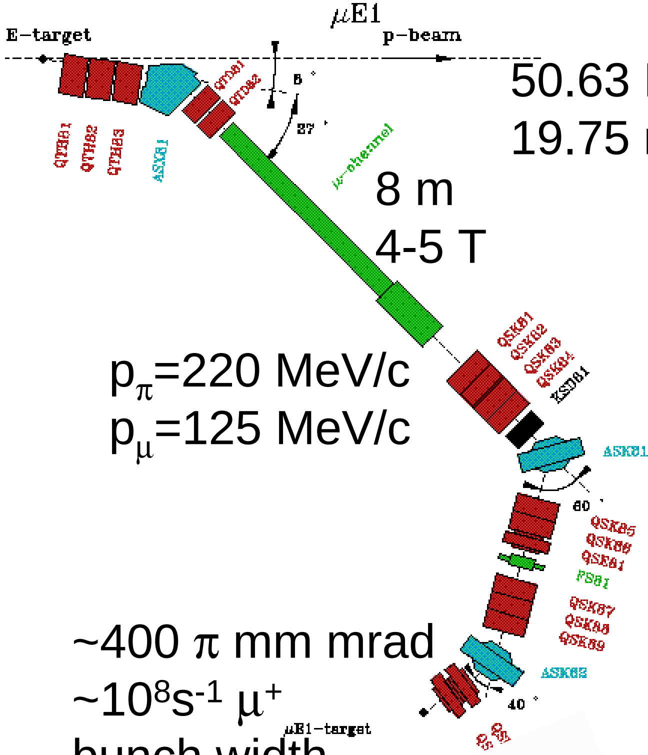
E=0.64MV/m, B=1.0T,
γ=1.57, R=0.5m, A=0.3, P=0.9

$$\sigma_{d_\mu} \approx \frac{2 \times 10^{-16}}{\sqrt{N}}$$

$$\sigma_{d_\mu} \approx \frac{1.1 \times 10^{-16}}{\sqrt{N}}$$

$$d_\mu = \eta e\hbar/4mc \approx \eta \times 4.7 \times 10^{-14}\,\mathrm{e\cdot cm}$$



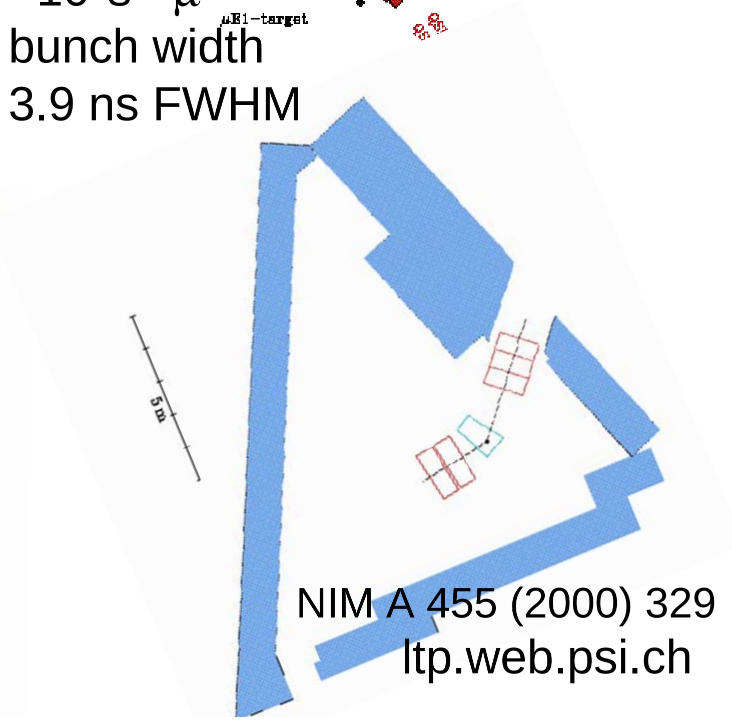


50.63 MHz
19.75 ns

8 m
4-5 T

p_π=220 MeV/c
p_μ=125 MeV/c

~400 π mm mrad
~$10^8 s^{-1}$ μ^+
bunch width
3.9 ns FWHM



NIM A 455 (2000) 329
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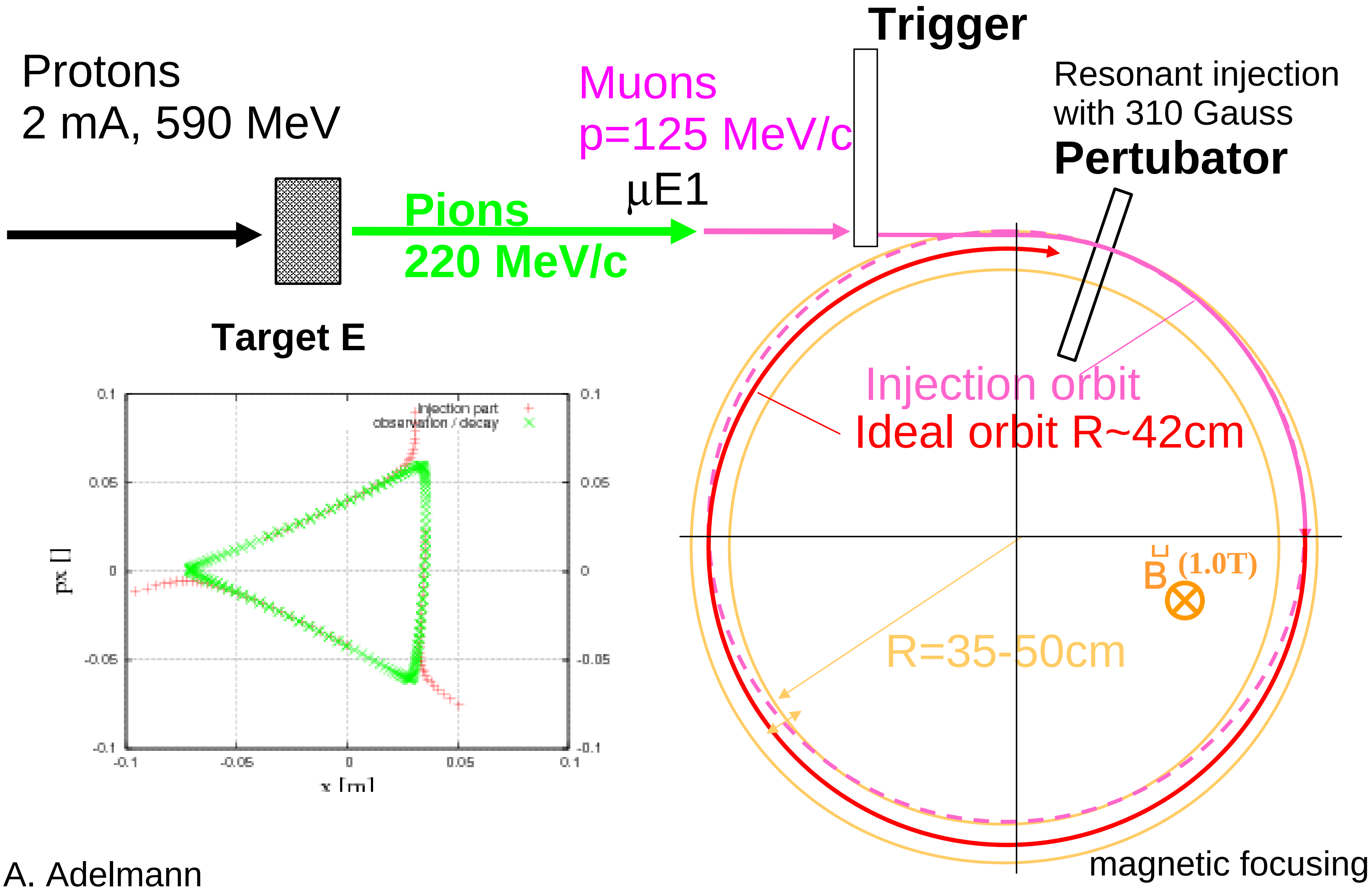
Idea

- Use existing μE1 beam at PSI
- Low momentum = „table top experiment“
- Inject one muon per time (later, one could possibly accumulate several), allow next muon after decay.
- Get 3 x $10^5 s^{-1}$ x 2 x 10^7 s / year ~ 6 x 10^{12} $year^{-1}$ assume 80% detection efficiency

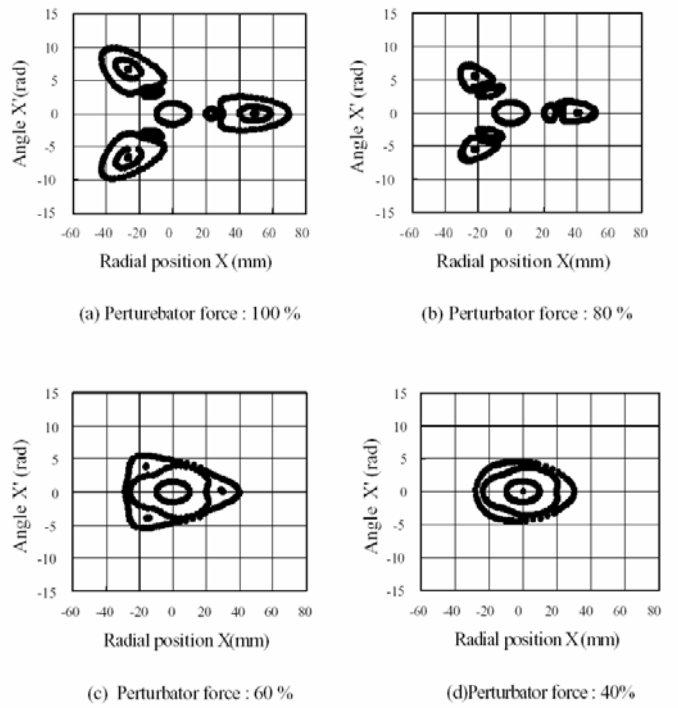
$$\Rightarrow \quad \sigma_{d_\mu} \approx 5 \times 10^{-23}\,\mathrm{e \cdot cm}$$

Compact Muon - Storage Ring Design

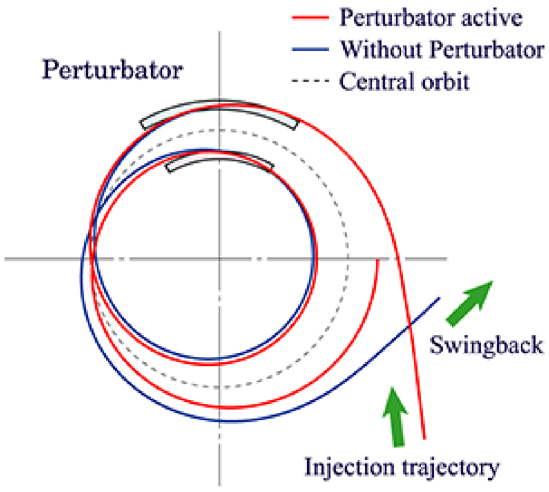


A. Adelmann

Fig. 2. Change in the phase diagram at the injection point as the perturbator force changes.



20 MeV electrons
6kA, 300ns,
30 mm mrad



▲ Injected electron beam trajectories

see also H. Yamada, NIM B199(2003)509

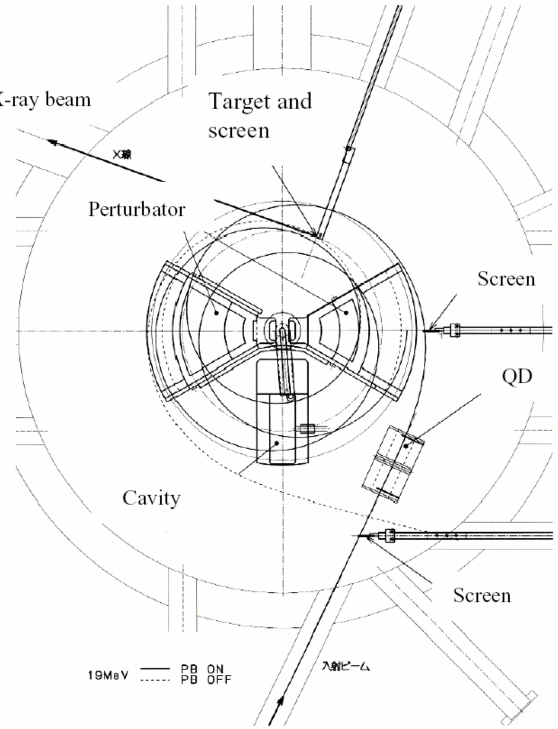
http://www.photon-production.co.jp/

Proceedings of the Second Asian Particle Accelerator Conference, Beijing, China, 2001

SUCCESSFUL BEAM INJECTION TO THE SMALLEST SYNCHROTRON AND BRILLIANT X-RAYS PRODUCTION

H. Yamada, T. Ozaki, Y. Sakai, D. Hasegawa, Y. Kitazawa, and I. Tohyama
Ritsumeikan University, 1-1 Nojihigashi, Kusatsu-City, 525
A.I. Kleev and G.D. Bogomolov
P.L.Kapitza Institute for Physical problems, Moscow, Russia

Fig. 1. Pair of perturbators, a microwave cavity, and a quadrupole doublet (QD) is placed inside the vacuum chamber under the strong magnetic field.



MIRRORCLE is an exact circular machine similar to AURORA. Purterbator (PB), the pair of one- turn coils to excite the betatron resonance, is placed under the main magnetic field, so the coil is made of air core and generates as much as 300 gaus. The pulse width of the

Systematic issues

- true EDM
- leading systematics:
  vertical E-field component
  $E_{II} / E_{radial} < 10^{-4}$
- detector rotation conspiracy with ω_a : alignment < 1 mrad
- time dependence of electron energy spectrum (magnetic field and detector acceptance)

CW	CCW	fast SR
+	-	
+	+	
		x
		x

Search for the muon electric dipole moment using a compact storage ring

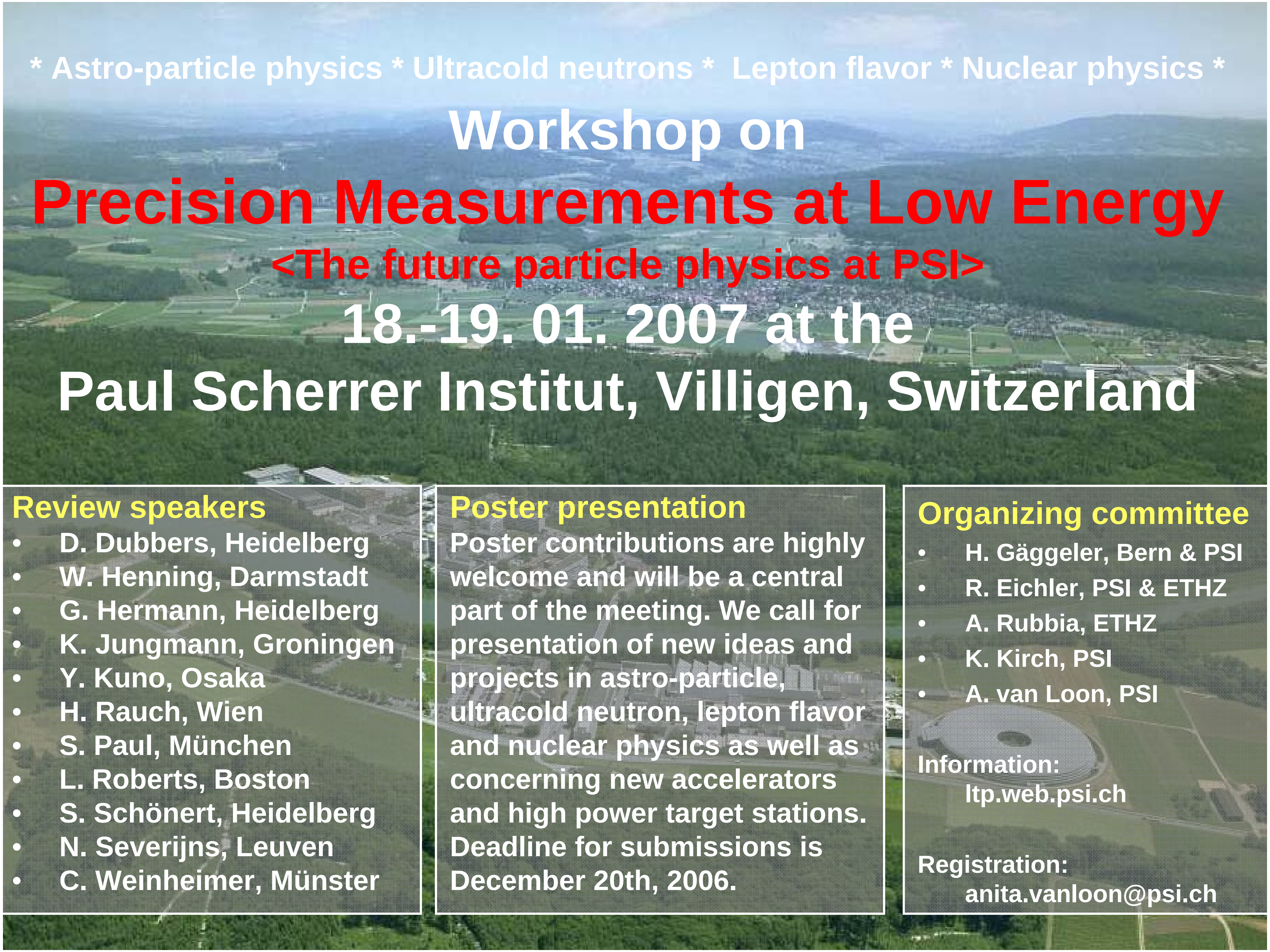
A. Adelmann and K. Kirch*
Paul Scherrer Institut (PSI), CH-5232 Villigen PSI, Switzerland
(Dated: June 16, 2006)

The recently proposed *'New Method of Measuring Electric Dipole Moments in Storage Rings'* [1, 2, 3] could be used in an experiment using the existing muon beam μE1 at PSI. A high muon polarization and a rather low momentum of $p_\mu \sim 125\,\mathrm{MeV/c}$ allow for an almost table-top storage ring and increase the intrinsic sensitivity and, thus, partially compensate for limitations due to lower event statistics. A measurement of the muon electric dipole moment with a sensitivity of better than $d_\mu \sim 5 \times 10^{-23}$ e·cm within one year of data taking appears feasible.

arXiv:hep-ex/0606034

Since then:
- work with **G. Onderwater** on systematic issues
- encouraging discussions with both, experimentalists and theoreticians
- work with **A. Adelmann** on realistic injection schemes

→ Can soon update the paper and perhaps undertake steps towards a LOI in case we can bring together a sufficiently strong group


* Astro-particle physics * Ultracold neutrons * Lepton flavor * Nuclear physics *
Workshop on
Precision Measurements at Low Energy
<The future particle physics at PSI>
18.-19. 01. 2007 at the
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Review speakers
• D. Dubbers, Heidelberg
• W. Henning, Darmstadt
• G. Hermann, Heidelberg
• K. Jungmann, Groningen
• Y. Kuno, Osaka
• H. Rauch, Wien
• S. Paul, München
• L. Roberts, Boston
• S. Schönert, Heidelberg
• N. Severijns, Leuven
• C. Weinheimer, Münster
Poster presentation
Poster contributions are highly welcome and will be a central part of the meeting. We call for presentation of new ideas and projects in astro-particle, ultracold neutron, lepton flavor and nuclear physics as well as concerning new accelerators and high power target stations. Deadline for submissions is December 20th, 2006.
Organizing committee
• H. Gäggeler, Bern & PSI
• R. Eichler, PSI & ETHZ
• A. Rubbia, ETHZ
• K. Kirch, PSI
• A. van Loon, PSI
Information:
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anita.vanloon@psi.ch

PAUL SCHERRER INSTITUT PSI

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