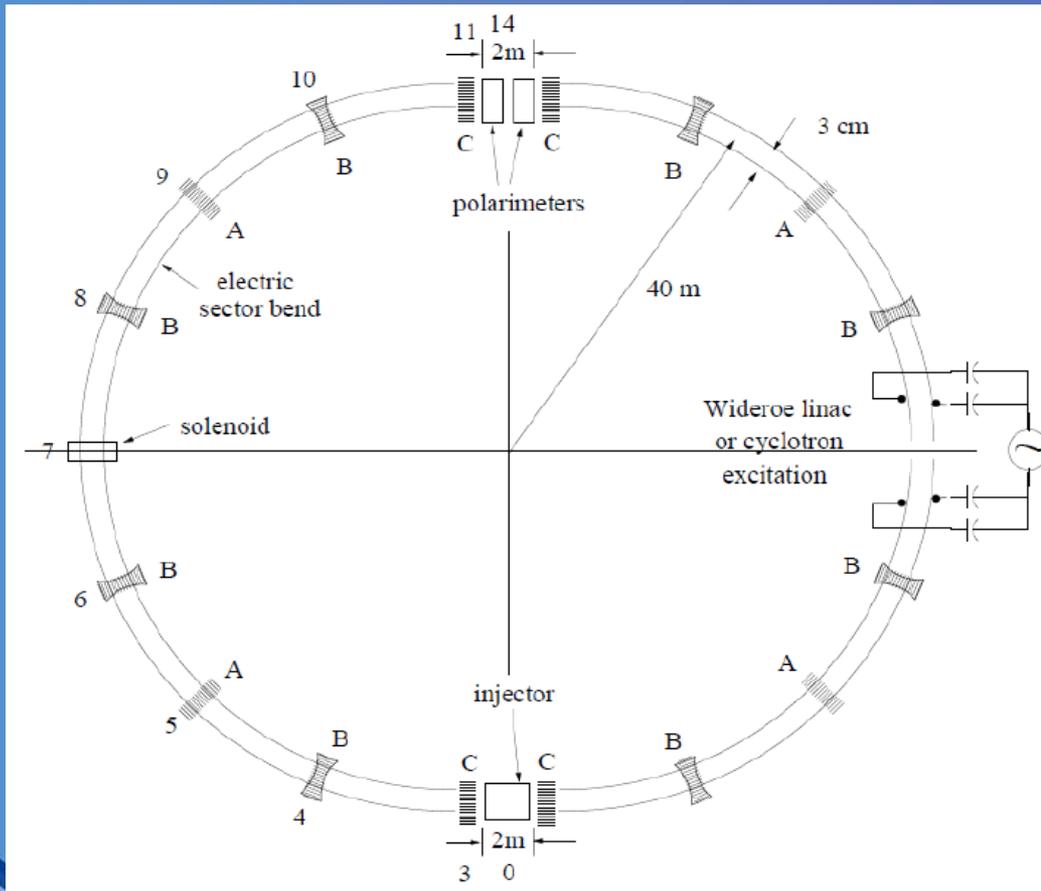


Storage Ring EDM Measurements, and How They Might Fit In @ BNL

Steve Vigdor
pEDM Review
March 14, 2011



BROOKHAVEN
NATIONAL LABORATORY

a passion for discovery

History of Storage Ring EDM Proposals @ BNL

- *Outgrowth of E821 storage ring experiment to measure muon $g-2$, and concepts for improved sensitivity to muon EDM*
- *Developed into LOI to RHIC/AGS PAC (2006, 2007) for exp't to measure deuteron EDM, using both E and B fields in storage ring. Received mention in 2007 Long Range Plan among “targeted program of experiments to investigate neutrino properties and fundamental symmetries...to discover...key ingredients of the New Standard Model...”*
- *Deuteron EDM proposed to PAC in May 2008. PAC found science compelling, but noted lack of focus on clear, staged realization plan, involving R&D and intermediate-sensitivity experiment at existing ring. Urged ALD to convene technical review after Collaboration developed staged approach.*
- *Development of staged approach hinged on pEDM and ring with purely electrostatic bending. Technical review of concept took place at BNL Dec. 8-9, 2009. Review team: Y. Derbenev, B. Filippone, R. Holt, T. Roser, E. Sichtermann, S. Vigdor.*
- *2010-11 focus on fleshing out technical details, including ring lattice design, spin coherence time, E-field R&D, etc. and strengthening collab'n*

Comments from pEDM Review @ BNL, Dec. 2009

The Committee judges the proton EDM experiment to be intriguing, important and very challenging, and the overall design to be informed by many clever ideas, especially the use of the magic momentum and simultaneously counter-rotating beams. A proton EDM measurement to the goal sensitivity of 10^{-29} e·cm would represent a profound contribution to the search for non-Standard Model CP violation in nature. Furthermore, the unique systematics of a storage ring EDM search allow it to provide crucial independent confirmation of an EDM signal from another, more conventional, EDM experiment. While the Committee expresses a number of significant concerns about technical performance requirements needed for the experiment and about some of the proposed solutions, it has not identified anything considered to be a technical showstopper at this point. The Committee is thus enthusiastic about seeing this project move forward...

The Committee makes a number of specific recommendations herein for how the Collaboration should proceed to an R&D stage and toward a DOE critical decision regarding mission need for this experiment. It also suggests a number of technical issues that it feels need greater conceptual attention and/or crisper presentation. Overall, it finds that the project is at a suitable stage to launch serious discussions with funding agencies and with potential collaborating institutions, in order to strengthen the efforts moving forward.

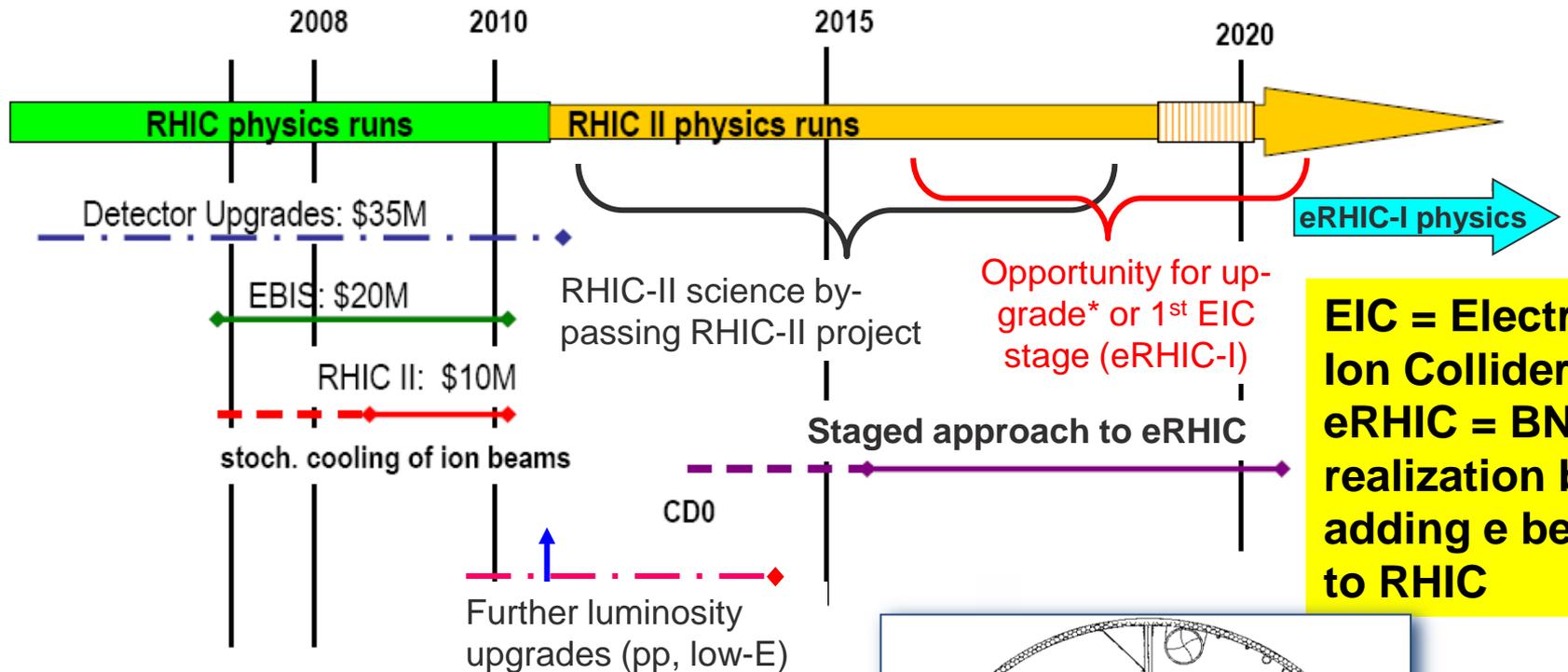
Comments from Oct. 2010 Review of Hadron Physics Plans at IKP FZ Jülich

An EDM search in a storage ring as proposed by the IKP for proton, deuteron and the ^3He nucleus at a sensitivity level of 10^{-29} e·cm would provide a guaranteed high visibility for the IKP as well as for the FZ Juelich. It would have significant scientific impact with any possible outcome if the design sensitivity goal is reached. ... For all these reasons, **the Council found the proposed storage ring EDM activities as the most compelling of the long-term future efforts proposed for hadron physics at Juelich.**

The EDM experiment at FZ Juelich will be very challenging and demanding. ... National and international high quality collaboration must be established with fully committed partners. In particular, **this experiment would largely benefit from partners from the neighboring universities and from taking advantage of the existing fruitful collaboration with the BNL based storage ring collaboration.**

The committee recommends that a study group be formed that works out a realistic, coherent and detailed project plan towards a 10^{-29} e·cm proton or deuteron EDM experiment. The plan should include an intermediate step. For this a reasonable budgeted experiment should be performed. ... **We recommend a review of the progress of the dedicated EDM study group by an international panel in one year time.**

A Long Term (Evolving) Strategic View for RHIC

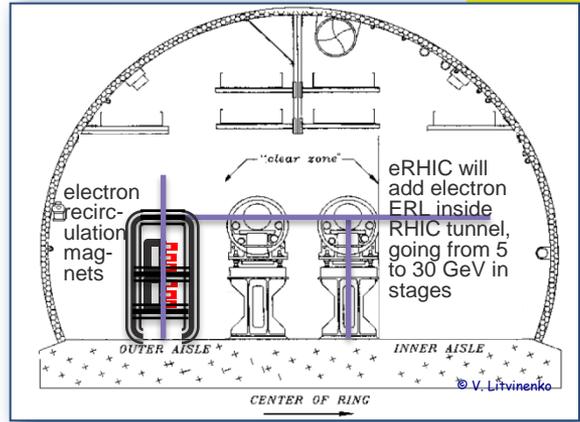


EIC = Electron-Ion Collider; eRHIC = BNL realization by adding e beam to RHIC

Legend:

- R&D
- ◀-----▶ Construction
- .-.-.-.-> Multiple small projects

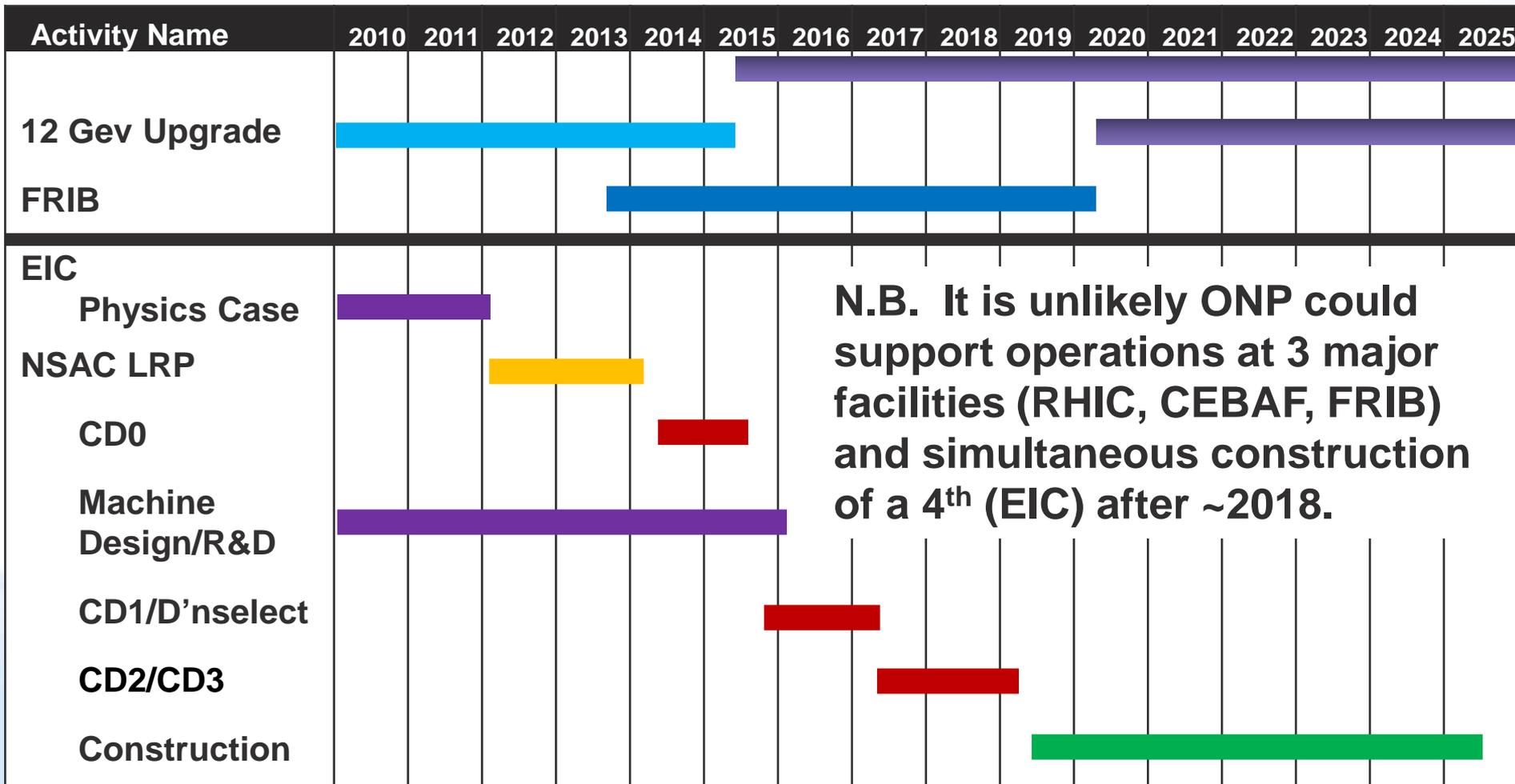
CD0: DOE Critical Decision, mission need



* New PHENIX and STAR Decadal Plans provide options for this period. Dedicated storage ring for novel charged-particle EDM measurements another option.

Potential Electron-Ion Collider Timeline Shown by Hugh Montgomery at INT Workshop, Sept. 2010

EIC Realization Imagined

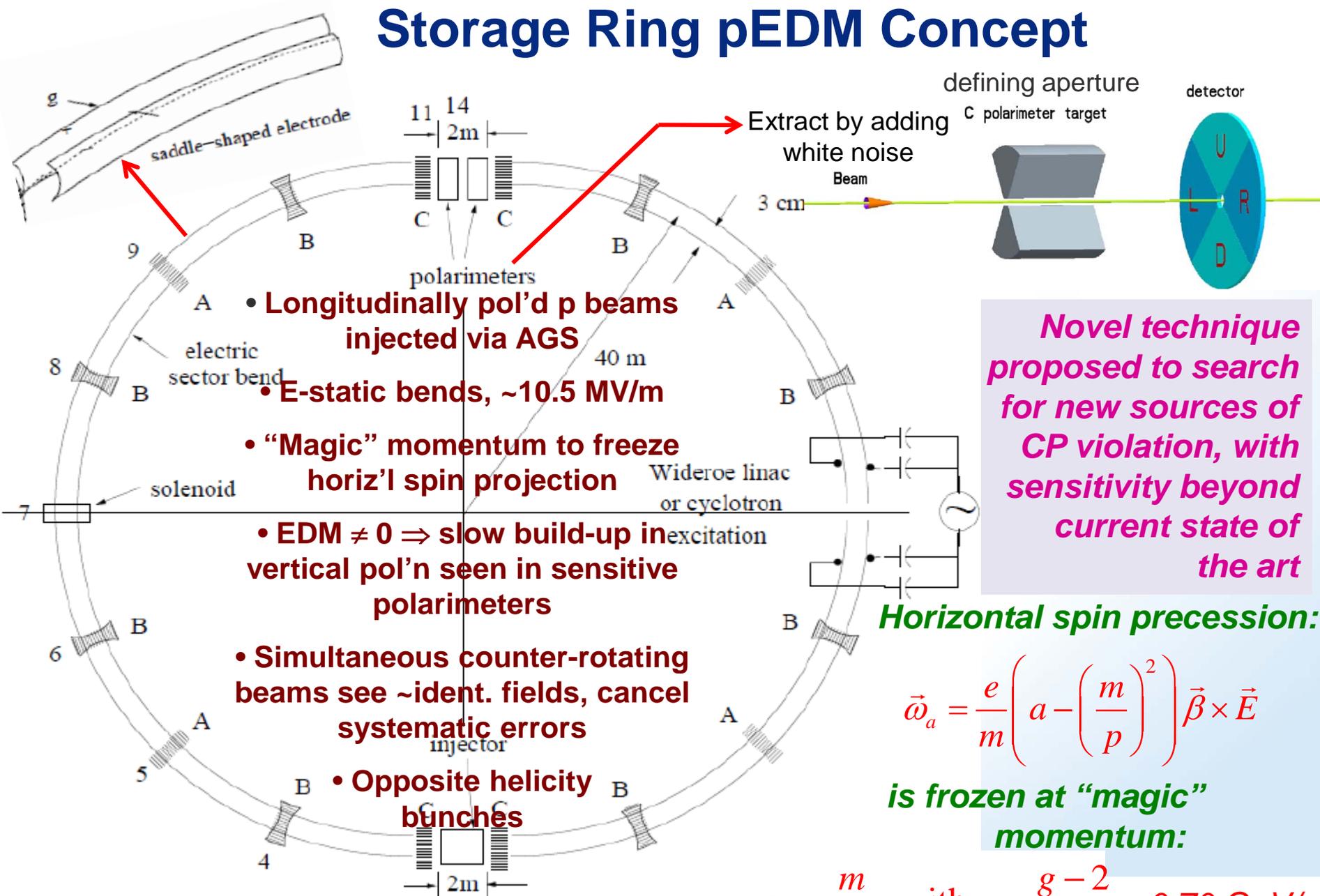


Other Relevant Background

- *Funding for pEDM would most naturally fall within the Low Energy Program of the Office of Nuclear Physics (ONP) at DOE, which has traditionally funded other EDM efforts.*
- *ONP (together with NSF) is currently funding a next-generation nEDM project for SNS, whose initial goal was 10^{-28} e·cm. nEDM project has undergone substantial cost growth and sensitivity reduction, and is currently part of the scope of an NSAC charge to reevaluate U.S. priorities in fundamental neutron science (report due by end of June 2011).*
- *To date, ONP has not responded positively to BNL requests to fund ~\$1.5M/year for pEDM scientists and R&D. Funding has come primarily from BNL LDRD, which has now terminated.*
- *SREDM Collaboration is planning to submit CD-0 proposal to ONP. If CD-0 (“Mission Need”) is granted, project R&D funds could become available.*
- *While pEDM is not within “mainstream” of RHIC science, it could provide a high-payoff, low-operations-cost alternative to RHIC running, or fill in for RHIC ops. during eRHIC construction. But EDM ring construction will not be cheap, and case for CD-0 must be highly compelling re tech. feasibility.*

Backup Slides

Storage Ring pEDM Concept



- Longitudinally pol'd p beams injected via AGS
- E-static bends, ~10.5 MV/m
- "Magic" momentum to freeze horiz'l spin projection
- EDM ≠ 0 ⇒ slow build-up in vertical pol'n seen in sensitive polarimeters
- Simultaneous counter-rotating beams see ~ident. fields, cancel systematic errors
- Opposite helicity bunches

Novel technique proposed to search for new sources of CP violation, with sensitivity beyond current state of the art

Horizontal spin precession:

$$\vec{\omega}_a = \frac{e}{m} \left(a - \left(\frac{m}{p} \right)^2 \right) \vec{\beta} \times \vec{E}$$

is frozen at "magic" momentum:

$$p = \frac{m}{\sqrt{a}}, \text{ with } a = \frac{g-2}{2} = 0.70 \text{ GeV/c for protons}$$

• Need ~1000s spin coherence time, ~2 × 10⁷s counting time to attain 10⁻²⁹ e·cm stat. sensitivity