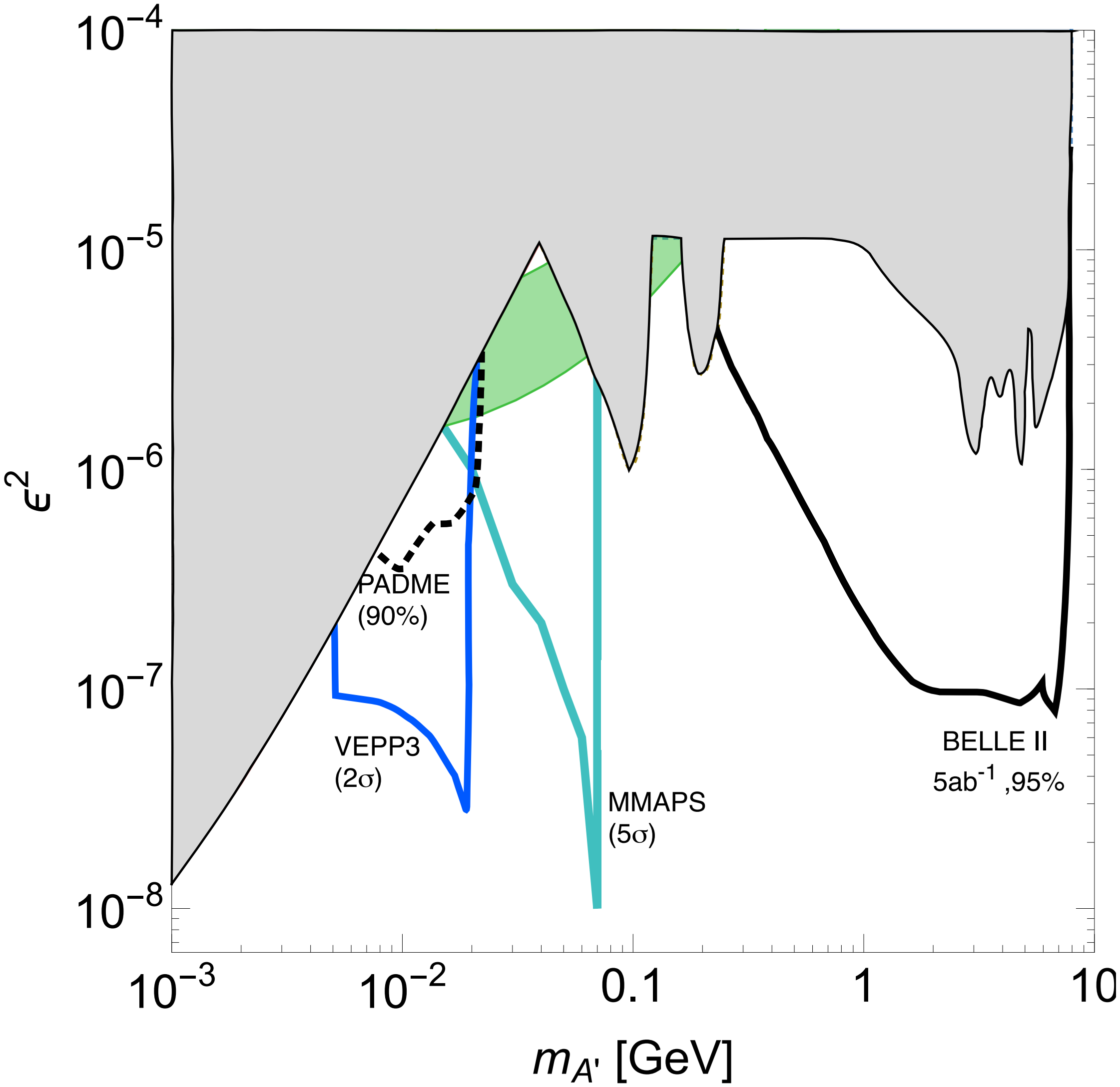
Dark Matter and Very Asymmetric Collider

David Douglas and Bogdan Wojtsekhowski

Thomas Jefferson National Accelerator Laboratory

The mass range of current interest



Searching for a ***U*** boson with a positron beam

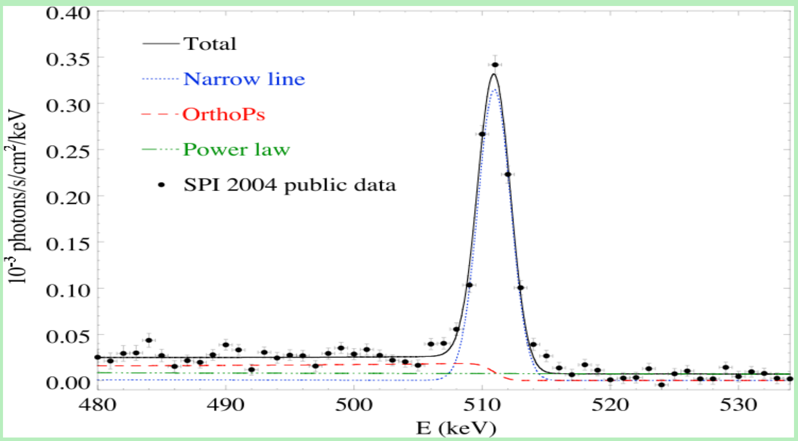
Bogdan Wojtsekhowski
Thomas Jefferson National Accelerator Facility

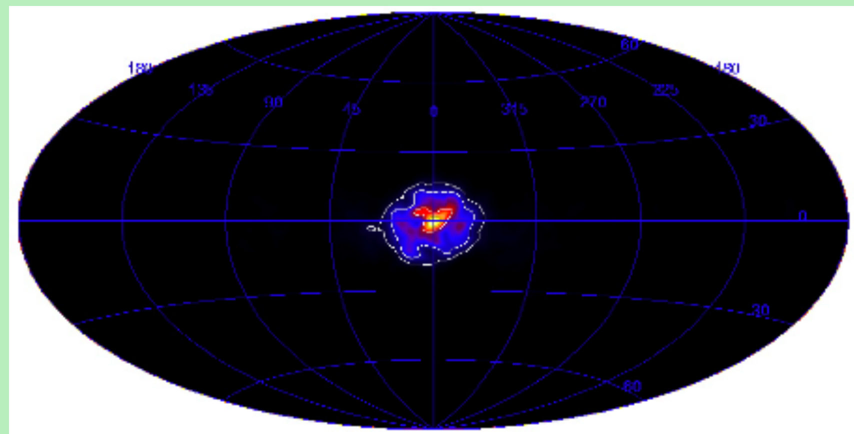
- The light dark matter
- Properties of a U boson
- Design of the experiment and expected sensitivity

Oct. 27, 2006 DNP APS Nashville

The case of the Light Dark Matter

The 511 keV line in the spectra of photons





Photon energy spectrum

Location of the source

P. Jean etal, Astron. Astrophys. 445, 579 (2006)

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From September 2006, NASA/SLAC

NASA Finds Direct Proof of Dark Matter

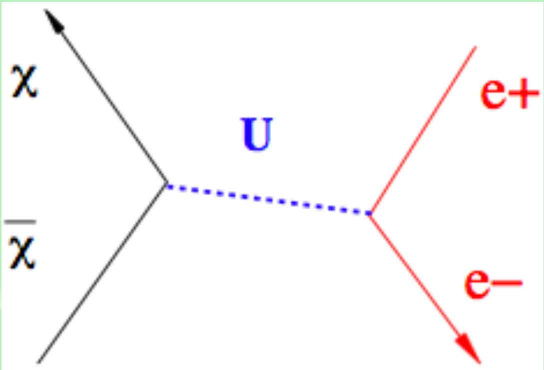
Dark matter and normal matter have been wrenched apart by the tremendous collision of two large clusters of galaxies. The discovery, using NASA's Chandra X-ray Observatory and other telescopes, gives direct evidence for the existence of dark matter.

"This is the most energetic cosmic event, besides the Big Bang, which we know about," said team member Maxim Markevitch of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

These observations provide the strongest evidence yet that most of the matter in the universe is dark. Despite considerable evidence for dark matter, some scientists have proposed alternative theories for gravity where it is stronger on intergalactic scales than predicted by Newton and Einstein, removing the need for dark matter. However, such theories cannot explain the observed effects of this collision.

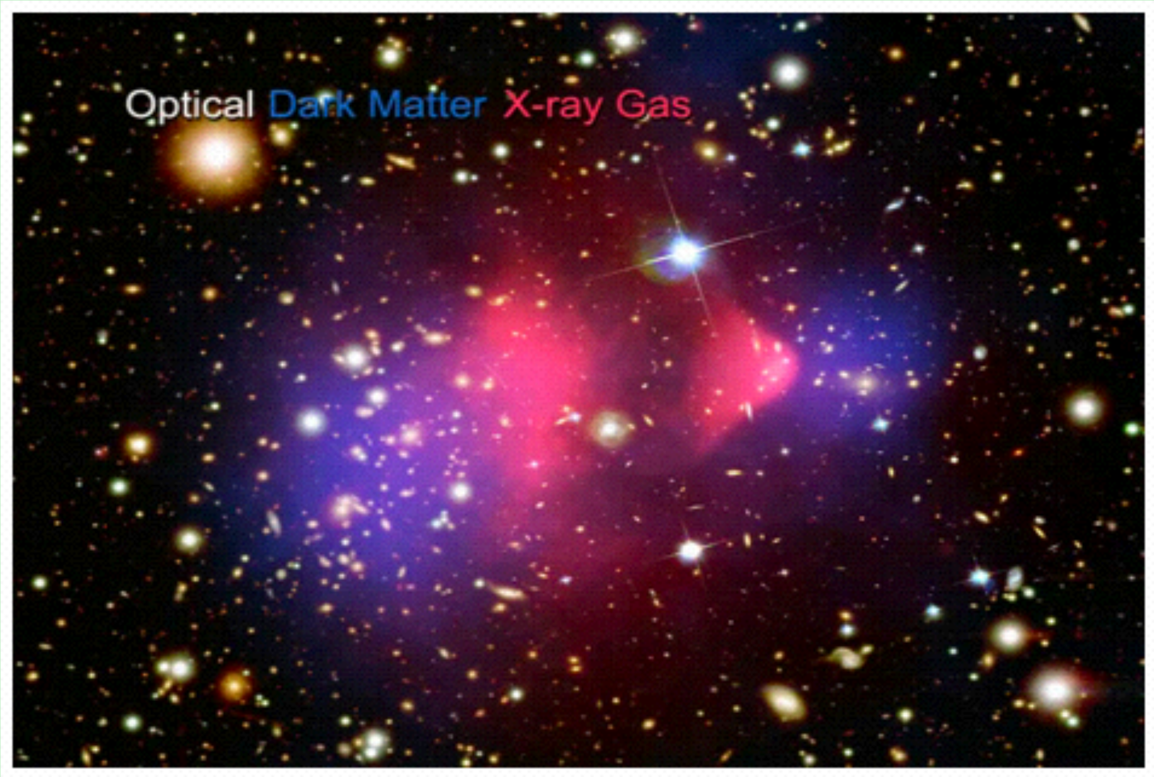
DARK matter directly observed in gravitational experiment
What is the nature and parameters of the constituents?

We will discuss the process:



Oct. 27, 2006 DNP APS N

From September 2006, NASA/SLAC



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What facility is needed for the search ?

A "very" low energy s ~ 10-20 MeV:
- includes large part of mass range
- allow to look for signal in U+γ mode
- lead to increase cross section ~ 1/s
- allow to use a fixed target approach

The answer: a positron beam of 100-400 MeV incident on the liquid hydrogen target

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Options for e^+e^- experiment at low s

$$m \sim \sqrt{4 \cdot E_+ \cdot E_-}$$

A "very" low energy s ~ 10-500 MeV

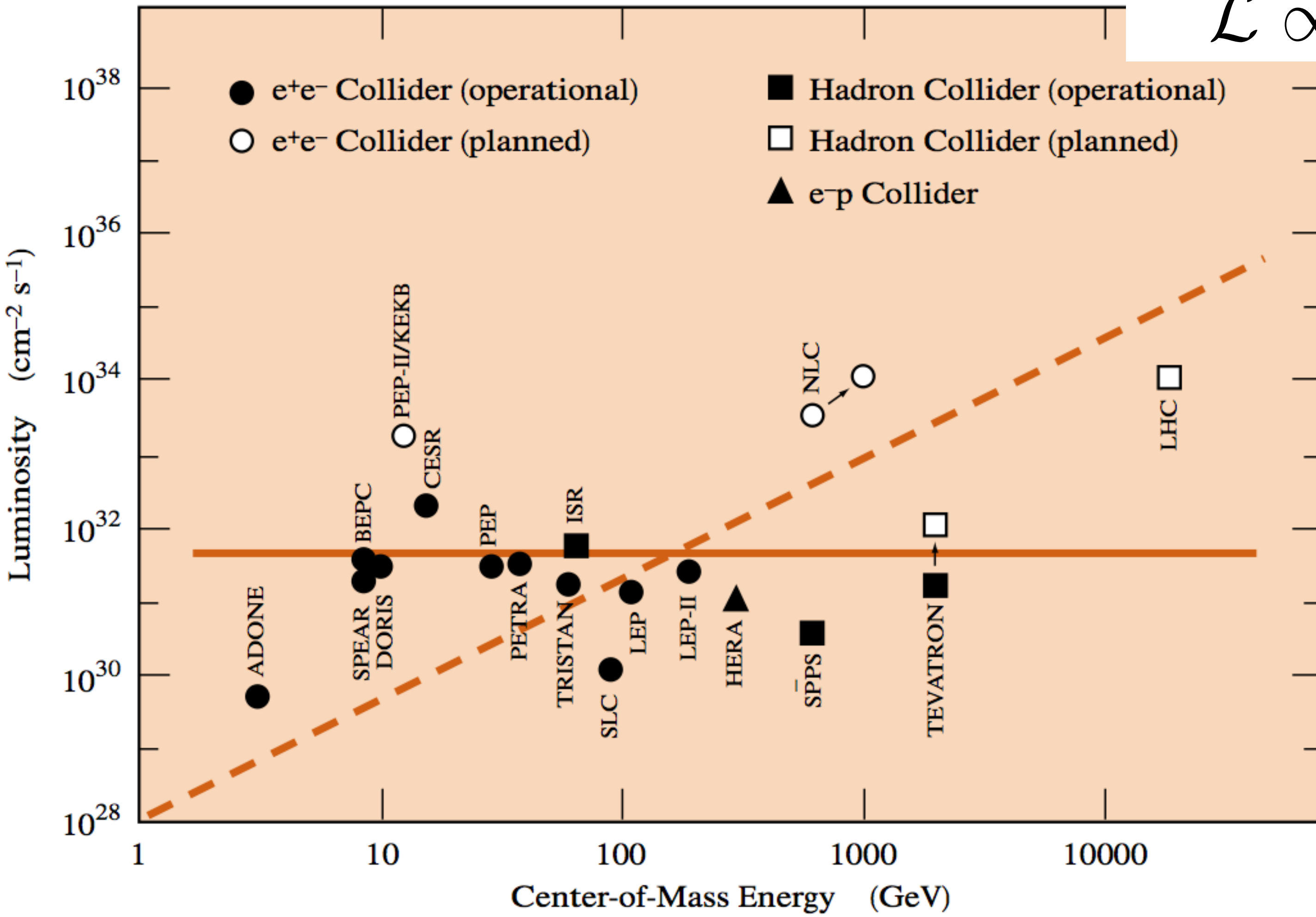
a) Search in existing data from good detector => limited mass resolution at low s
b) 5 MeV x 5 MeV collider of e+e- => very low luminosity
c) Sliding beams of e+e- (200 MeV x 200 MeV)=> need specialized accelerator with two rings
d) Positron beam and atomic electrons, m < 70 MeV

e) A head-head collider for the mass range 100-500 MeV

Luminosity of the colliders

from W. Panovsky's article in BEAM LINE

Dashed line is
$\mathcal{L} \propto E_{cm}^2$



For E_{cm}=100 MeV $\mathcal{L} \sim 10^{26} - 10^{29} cm^{-2}/s$

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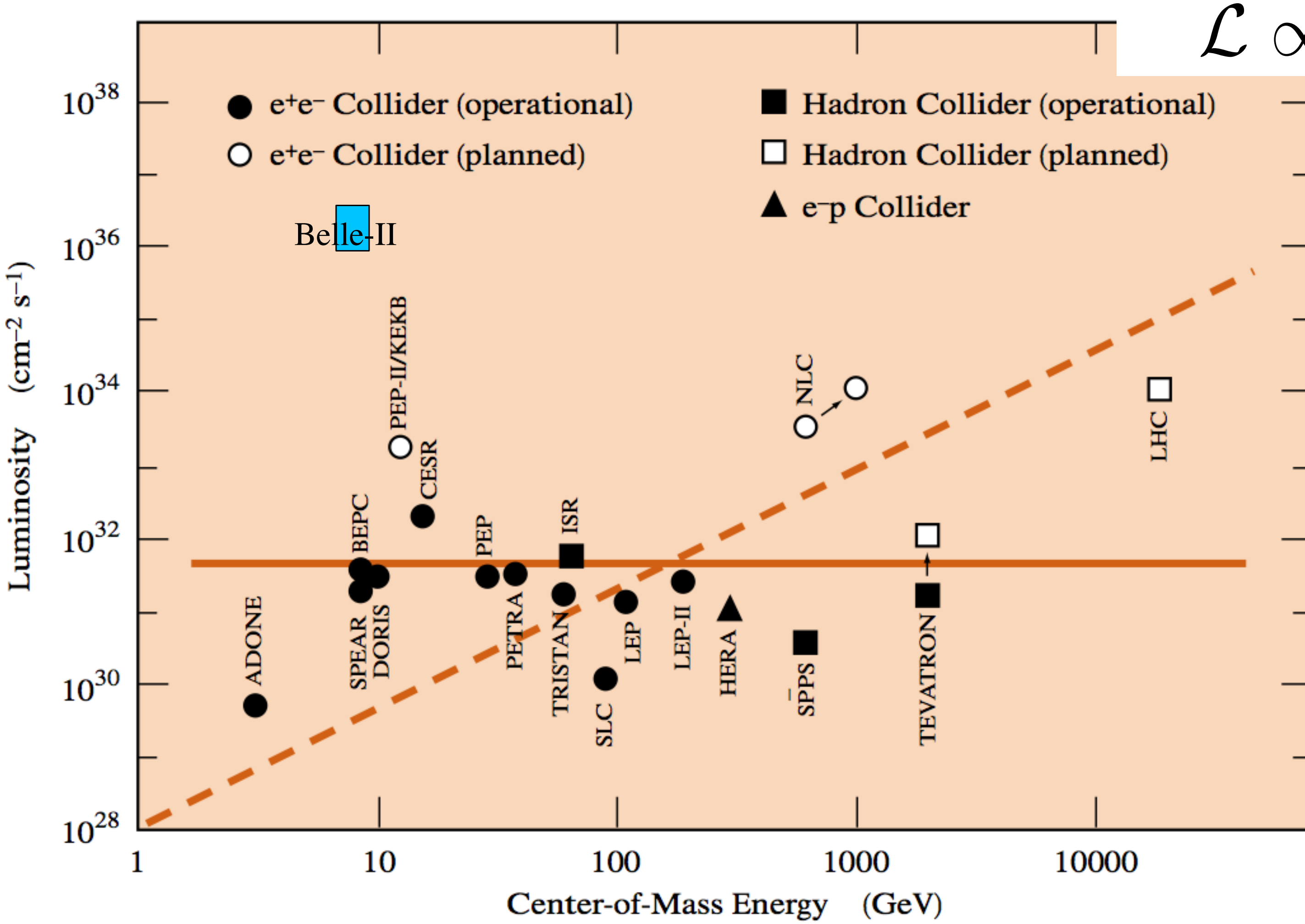

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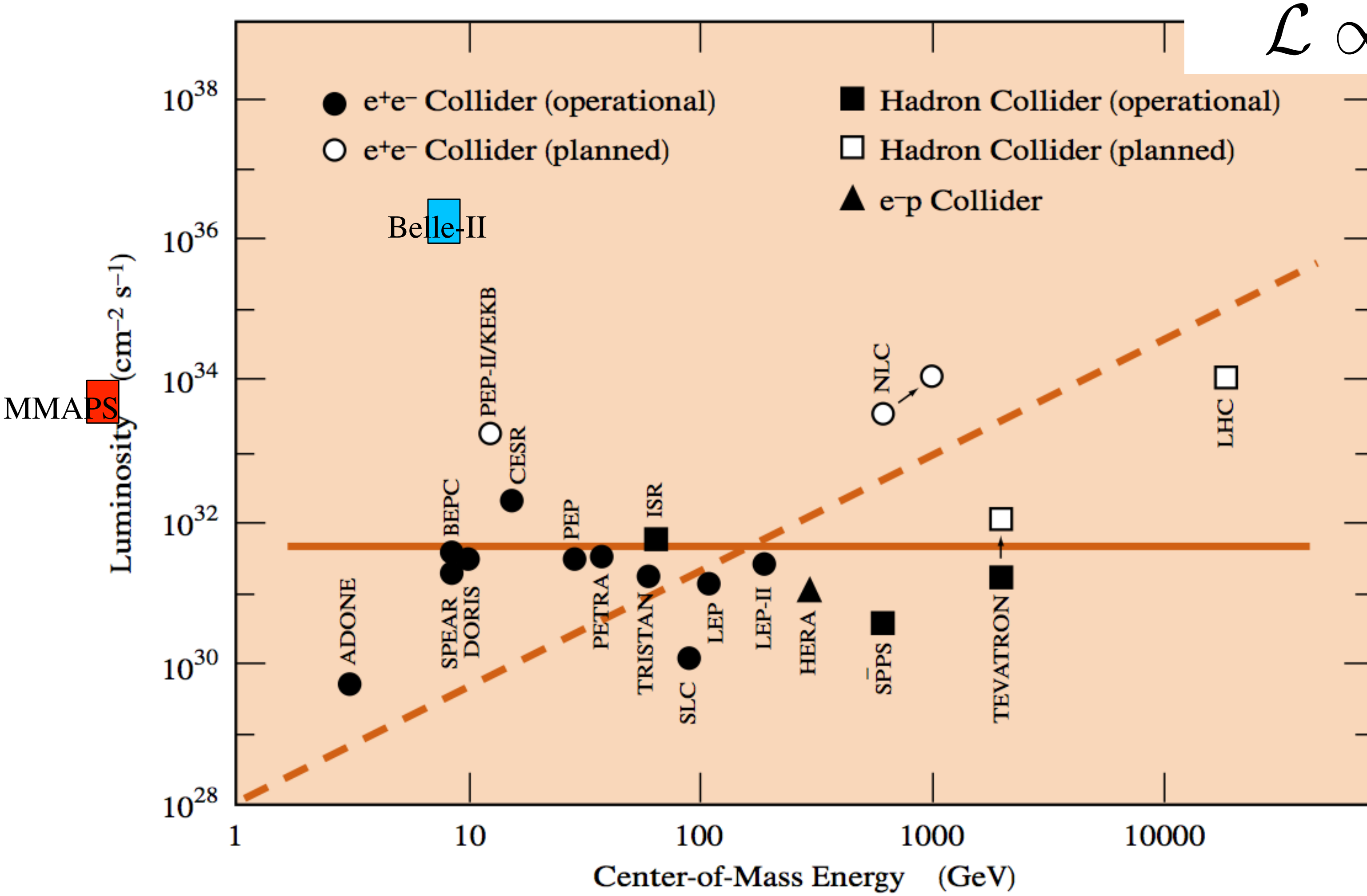

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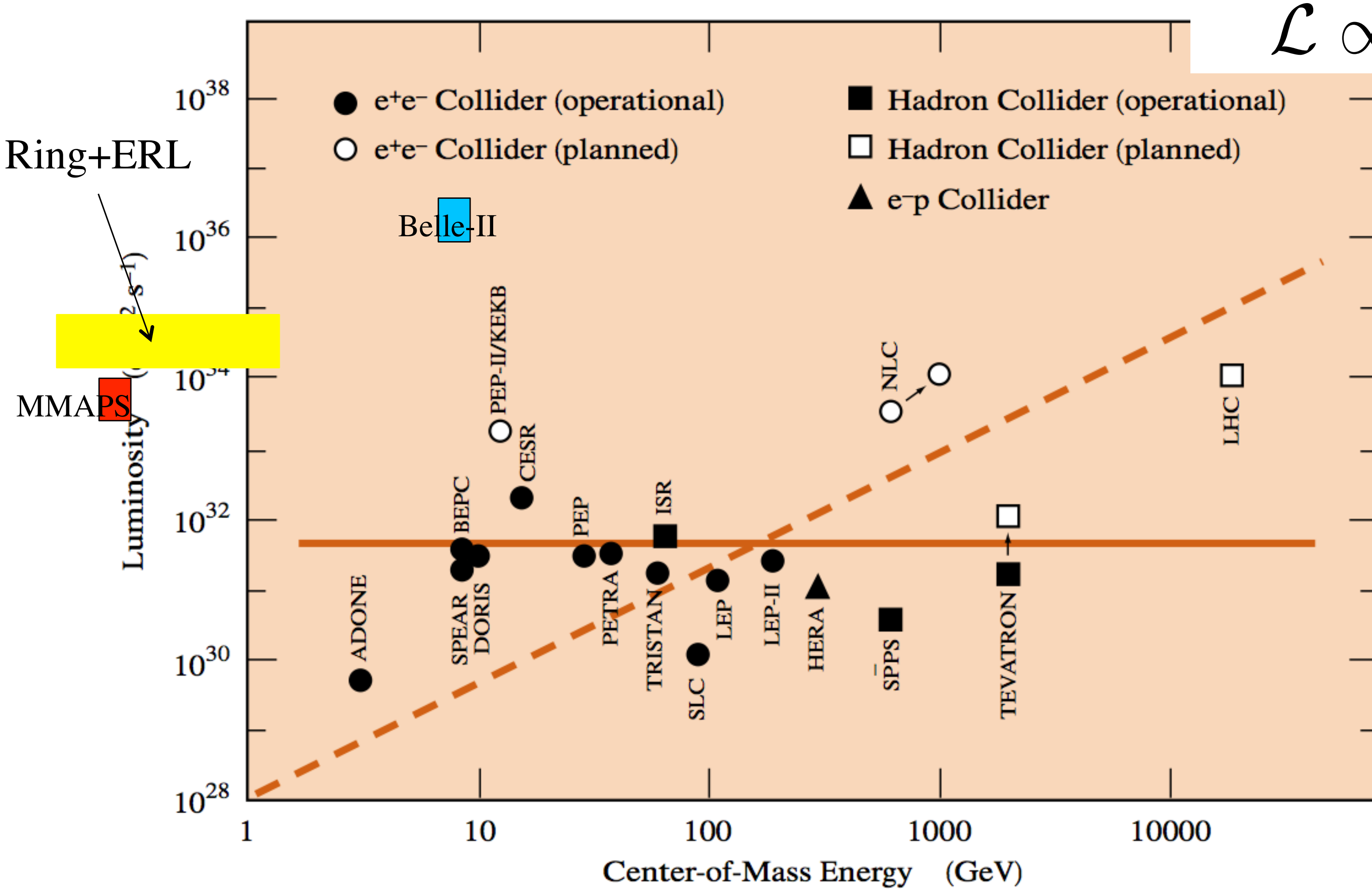
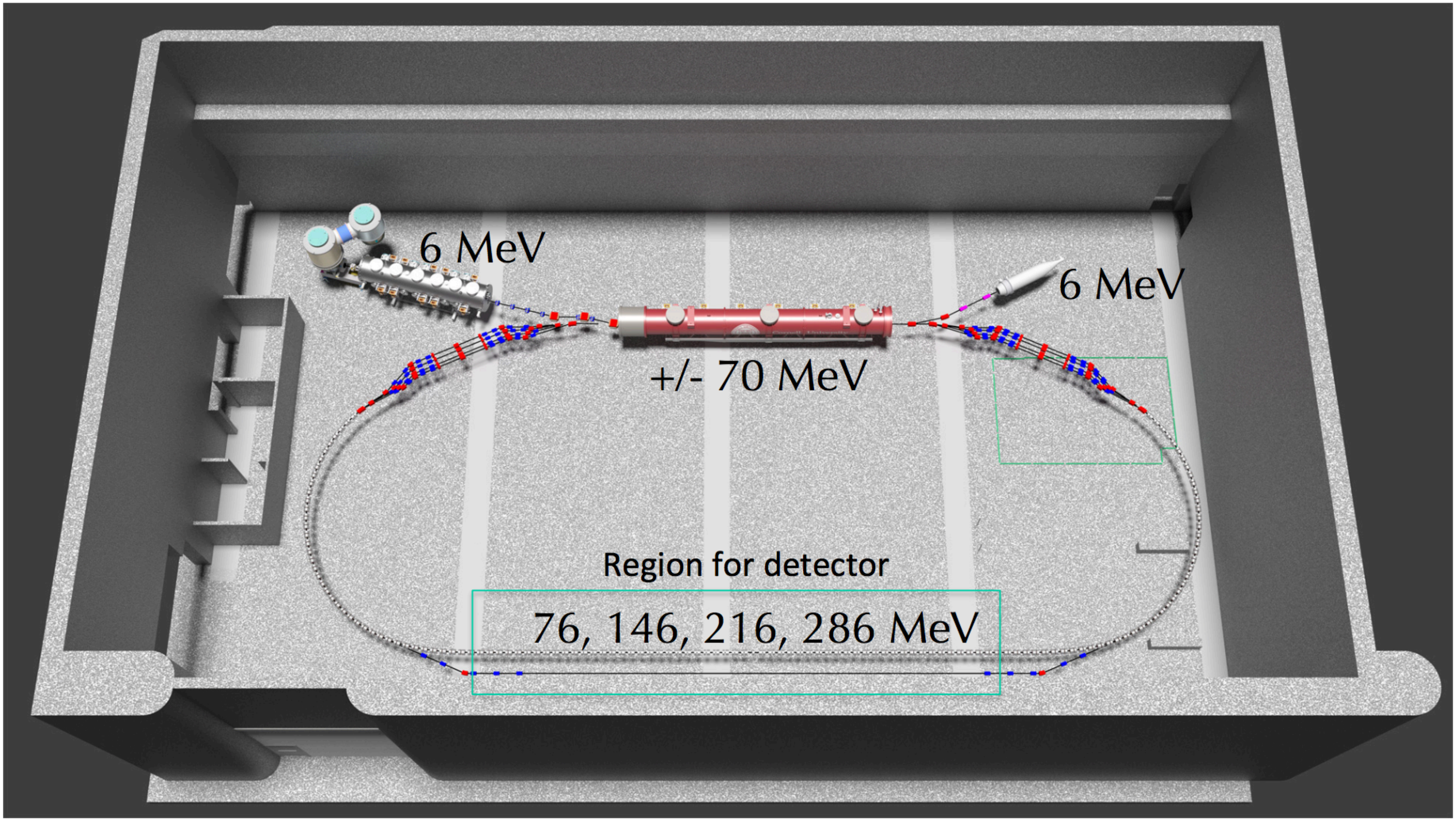


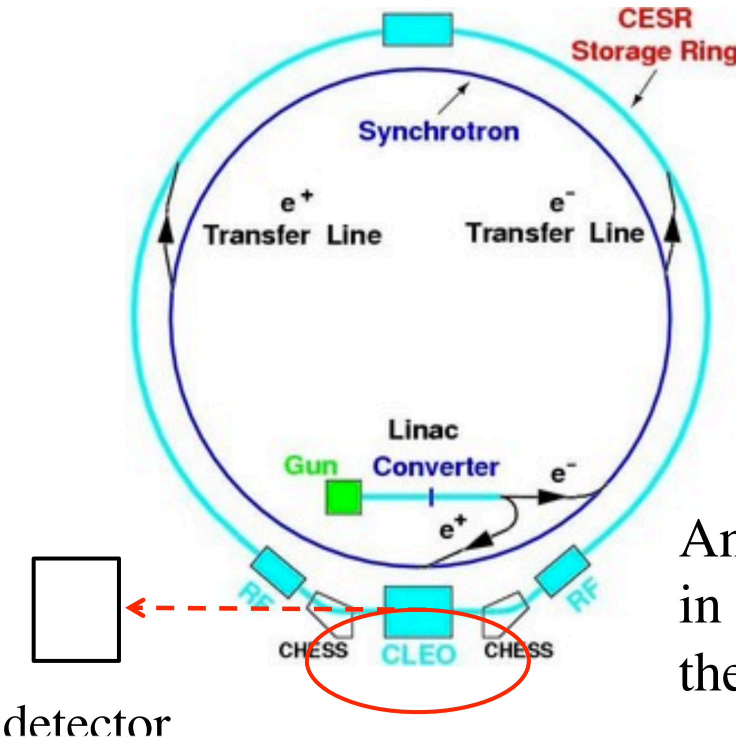
For E_{cm}=100 MeV $\mathcal{L} \sim 10^{26} - 10^{29} cm^{-2}/s$

Goal: 4-turn FFAG ERL at 16MV/m



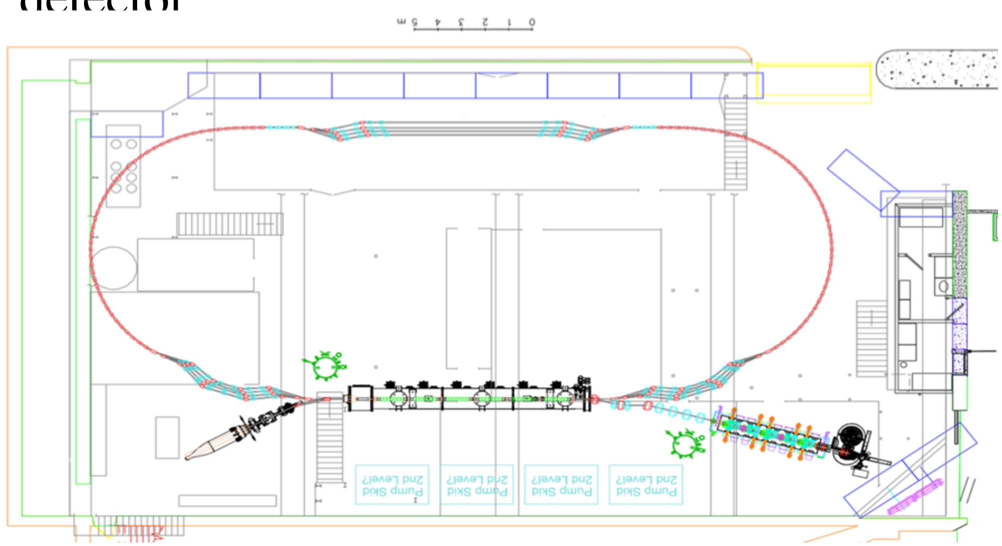
A new concept: Very Asymmetric Collider CESR+ERL

In 2015



up to 5 GeV x 0.3 GeV

An electron beam of 100 mA in the ERL is focused to match the e^+ CESR beam



A new concept: Very Asymmetric Collider

Proceedings of the 1988 Linear Accelerator Conference, Williamsburg, Virginia, USA

In 1988

A BEAUTY FACTORY USING AN SRF LINAC AND A STORAGE RING*

J. J. Bisognano, J. R. Boyce, D. Douglas, S. Heifets
J. Kewisch, G. Krafft, R. Rossmanith

Continuous Electron Beam Accelerator Facility
12000 Jefferson Avenue
Newport News, Virginia 23606

Abstract

We present a brief review of accelerator facilities proposed for measuring CP violation in the B-meson system. In light of this comparison we discuss requirements for a B-factory using an e^+ storage ring beam colliding with a superconducting RF linac e^- beam to produce a luminosity of 10^{34} cm^{-2}sec^{-1}.

Introduction

Interest in B-physics has increased dramatically in recent years driven in part by the standard model prediction of large CP violation in the B-meson system and also in part by advances in accelerator physics.[1−4] One of the more promising methods whereby sufficient $B\overline{B}$'s are produced is by e^+e^- collisions at the $\Upsilon(4S)$ at $\approx$ 10 GeV. The fundamental challenge in this approach is to achieve beam conditions such that the luminosity at the interaction point (IP)

$$L = \frac{N_e N_p f_c}{4\pi\sigma_x\sigma_y} H_D \approx 10^{34}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1} \qquad (1)$$

ing the positron beam; and finally, vary the frequency, beam sizes, and energies, all consistent with the first two steps, to calculate L.

Storage Ring Limitations

The success of light source rings implies a current of 1 amp, though ambitious, is feasible. This, along with a collision frequency f_c, gives the number of positrons in a bunch, N_p.

Second, the critical impedance for single bunch microwave instability is given by:

$$\left|\frac{Z_{\parallel}}{n}\right| = \sqrt{\frac{\pi}{2}} Z_o \alpha\gamma\sigma_\delta{}^2\sigma_z / N_p r_e \qquad (2)$$

where $\left|\frac{Z_{\parallel}}{n}\right|$ is the effective longitudinal impedance, Z_o is the vacuum impedance (=377 Ω), γ is in units of $m_o c^2$, σ_δ is the bunch energy spread, σ_z is the bunch length, N_p is the number of positrons in the bunch, and r_e is the classical electron radius.

A new concept: Very Asymmetric Collider

Study of Asymmetric ϕ Factory Options*

David B. Cline
University of California Los Angeles
Center for Advanced Accelerators, Physics Department
405 Hilgard Ave., Los Angeles, CA 90024-1547

Alper A. Garren
Lawrence Berkeley Laboratory
Accelerator and Fusion Research Division
1 Cyclotron Road, Berkeley, CA 94720
and
The UCLA Center for Advanced Accelerators

UCLA–CAA00108–4/94

In 1994

Abstract

We review the scientific motivation of the development of asymmetric ϕ factories and discuss the various options. We describe two specific options: (1) a high energy e^- linac colliding with a low energy e^+ storage ring, (2) a high energy e^- storage ring colliding with a low energy e^+ storage ring. A critical comparison of these options will be discussed.

A new concept: Very Asymmetric Collider

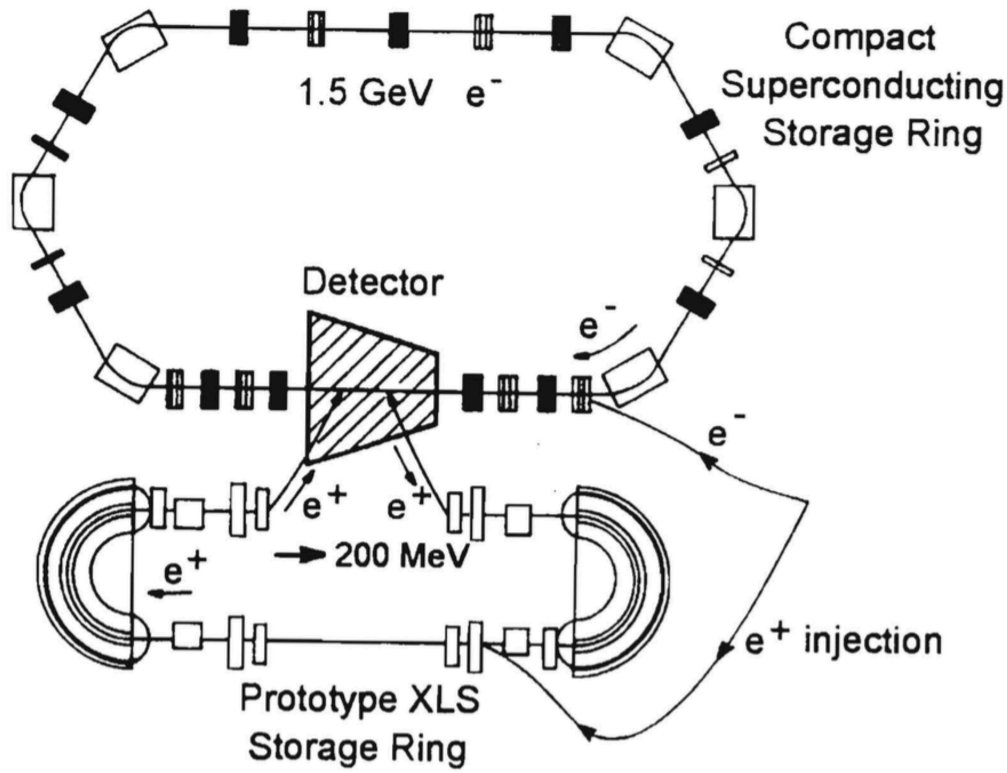
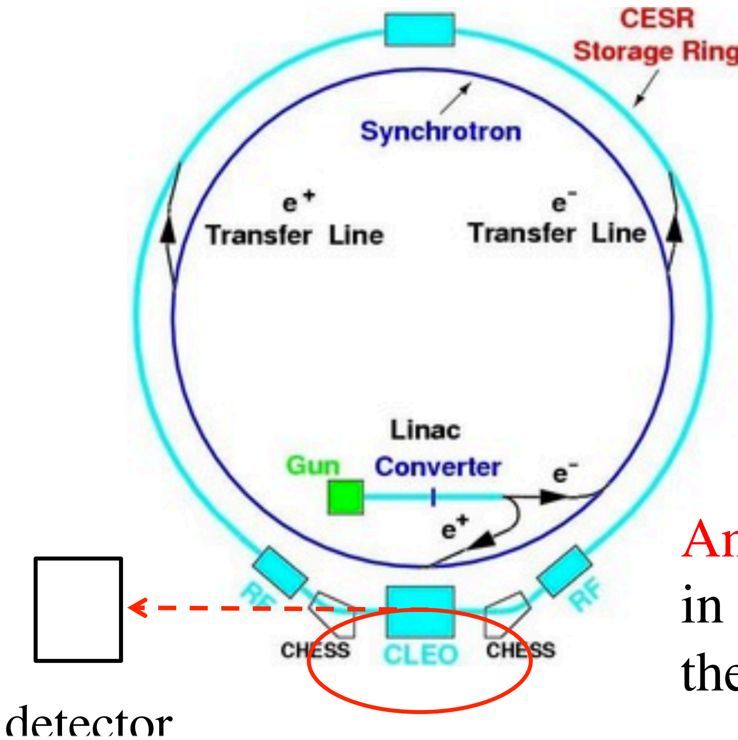


Figure 3: Schematic layout of an asymmetric ϕ factory using two storage rings. The interaction region has not been studied in this paper. [See Reference 9.]

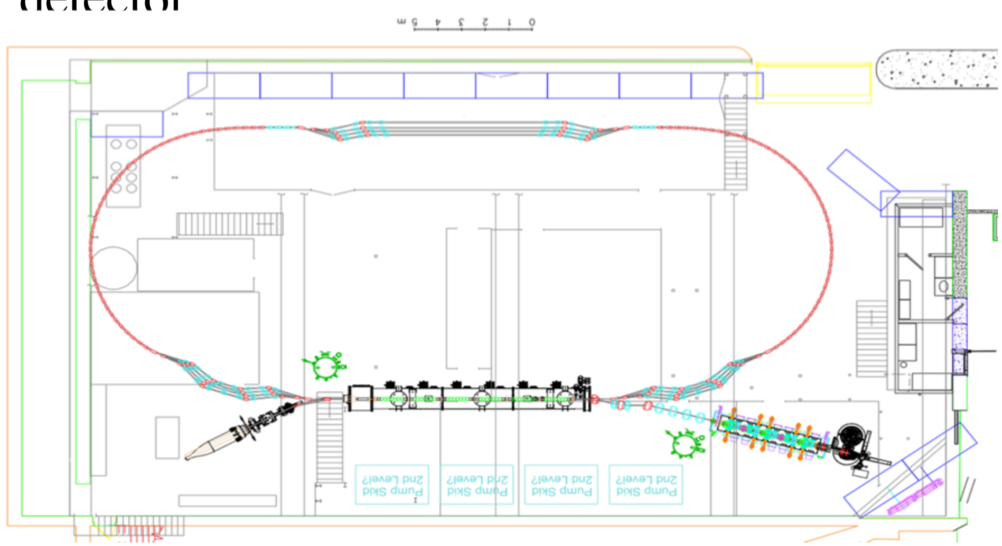
A new concept: Very Asymmetric Collider CESR+ERL

In 2015

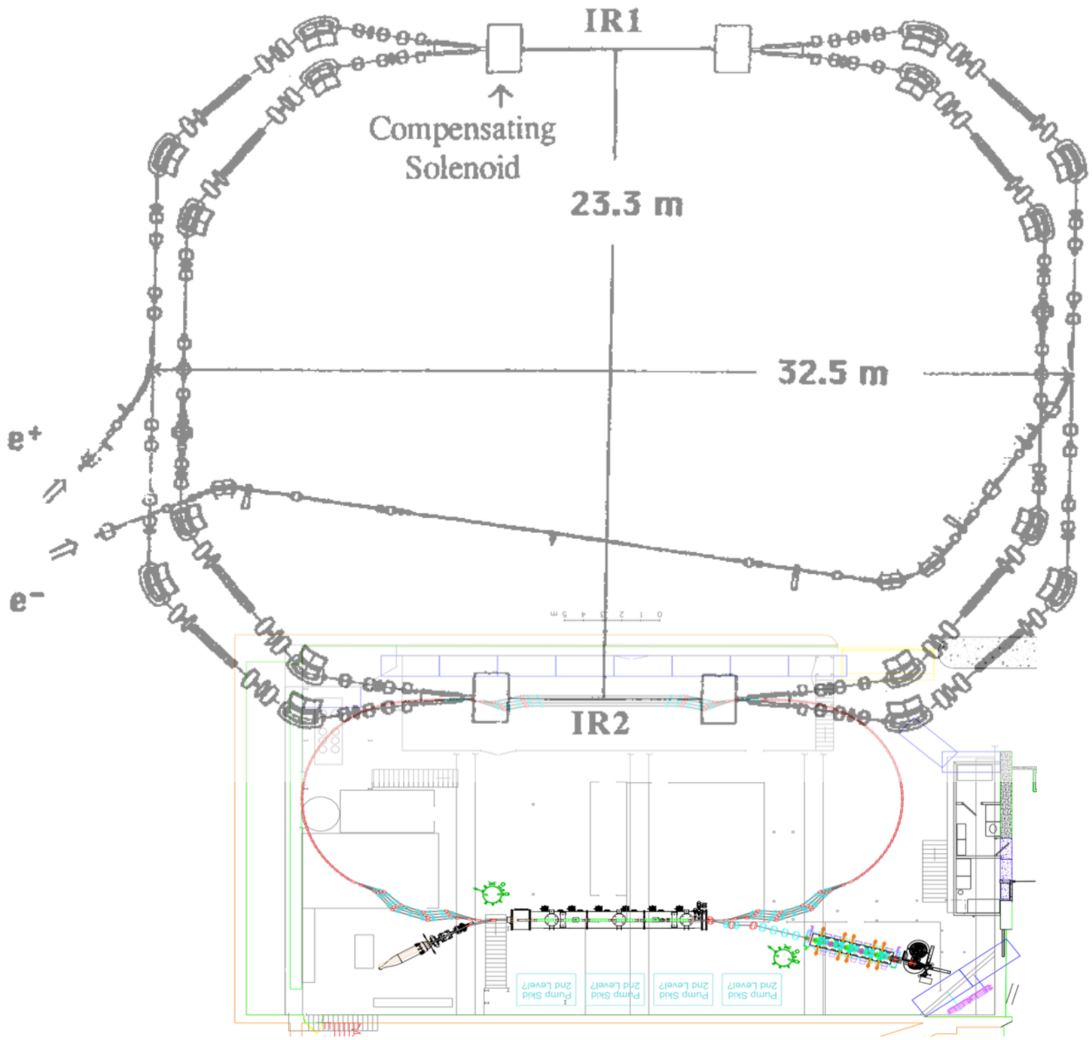


up to 5 GeV x 0.3 GeV

An electron beam of 100 mA in the ERL is focused to match the e^{+} CESR beam



A new concept: Very Asymmetric Collider
CESR+ERL or/and DAFNE+ERL



0.5 GeV x 0.1 GeV

The mass up to 400 MeV

An electron beam of 100 mA in the ERL is focused to match the e^+ DAFNE beam

VAC for precision physics

A Very Asymmetric Collider @ Cornell with a positron beam of the ring and an electron beam of ERL could be the ultimate device for discovery and study of the Dark Photons in the mass range up to 1-2 GeV.

Luminosity

- Luminosity comes from charge (particles/bunch N_e, N_p), current (collision frequency f_c), and beam size (σ_x, σ_y)
- If beam-beam interaction is strong enough and bunch charges asymmetric, the "weak" bunch can be disrupted, providing enhancement of luminosity (H_D)
- For linac-ring systems (Bisognano *et al.*, LINAC'88)

$$\mathcal{L} = \frac{N_e N_p f_c}{4\pi\sigma_x\sigma_y} H_D$$

- Can evaluate luminosity for example system concepts
  - Cornell-BNL Cβ + CESR e^+
  - DAΦNE e^+ + JLab-style ERL at 100 MeV

Conclusions

- High energy e^+ on low energy e^- provides novel avenue to high luminosity
- CESR e^+ on Cβ a promising possibility for realization of proposed system configuration
- DAΦNE e+ on a JLab-like ERL offers similar opportunities!