Low-Energy Physics at LERF

$e^{\pm}$ @ LERF

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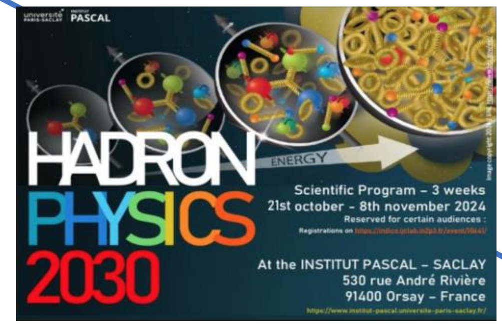

(i) Time opportunity
(ii) Ce⁺BAF
(iii) Physics opportunities
(iv) Instrumental requirements
(v) Summary

Time Opportunity

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CEBAF / Ce+BAF

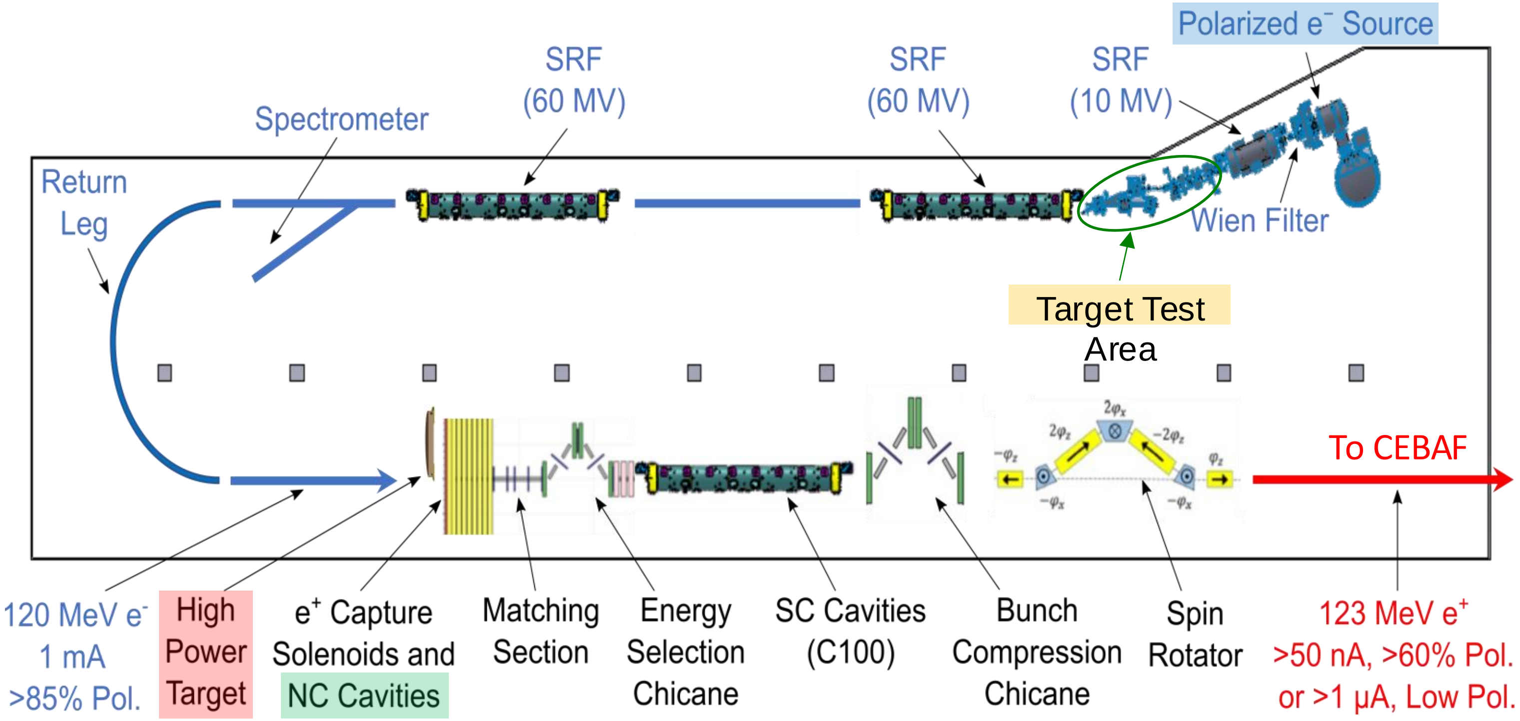
D. Higinbotham @ HP2030

Activities	Fiscal Year																		
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Positron Source (R&D)																			
Positron Project (potential)																			
Positron Physics																			

- On the basis of a notional DOE budget profile, Ce$^+$BAF construction may potentially start early 2030s for physics operation in mid 2030's.
- Meanwhile, the positron source R&D is progressing from the testing of the critical components towards a full implementation at LERF.
- Along this progress, new beam capabilities will become available for Physics at LERF.

e^+ @ LERF

- **Step 1a**: The critical risk areas (**mA polarized e⁻ source**, **high power target**, **capture cavities**) are currently investigated.
- **Step 1b**: Within the 2 coming years, a **10 MeV** high power test bench will be available at **LERF**.
- **Step 2**: The energy of the electron beam will be upgraded to Ce+BAF requirements (**120 MeV**).
- **Step 3**: The positron source will be implemented at **LERF**.



Physics Opportunities

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Low Energy Beams

Physics @ **LERF**
at **very low beam energies**

$I_e < 10$ mA $P_e > 80\%$ $T_e < 10$ MeV
$I_p < 10$ nA $P_p < 60\%$ $T_p < 10$ MeV
$I_p < 10^7\ e^+/s$ $P_p < 60\%$ $T_p < 1$ keV

- Slow Positron Physics and Applications
- Atomic physics
- Nuclear physics and astrophysics
- QED physics
- Others... ?

Physics @ **LERF**
at **low beam energies**

$I_e < 1$ mA $P_e > 80\%$ $T_e < 150$ MeV
$I_p > 50$ nA $P_p > 60\%$ $T_p < 123$ MeV
$I_p > 1\ \mu A$ $P_p < 10\%$ $T_p < 123$ MeV

- Nuclear physics and astrophysics
- QED physics
- Tests of the Standard Model
- Others... ?

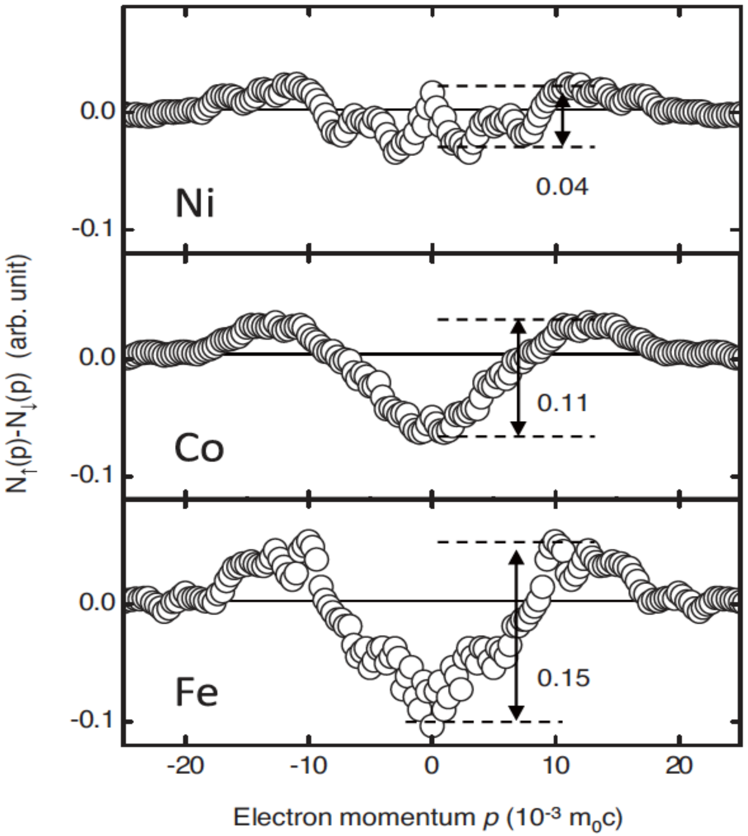
The intrinsic time limitation of these beam capabilities motivates a thorough investigation of their Physics reach.

E. Voutier

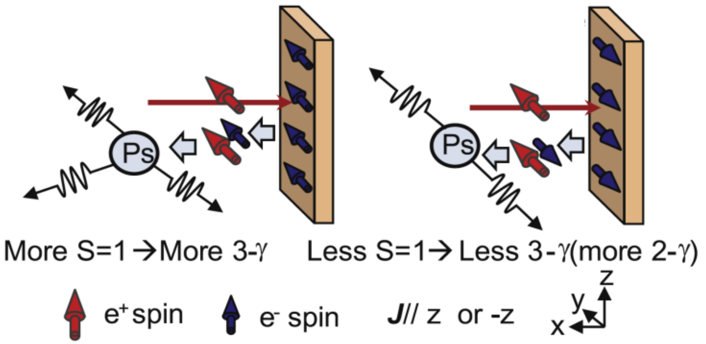
Positron Annihilation Spectroscopy

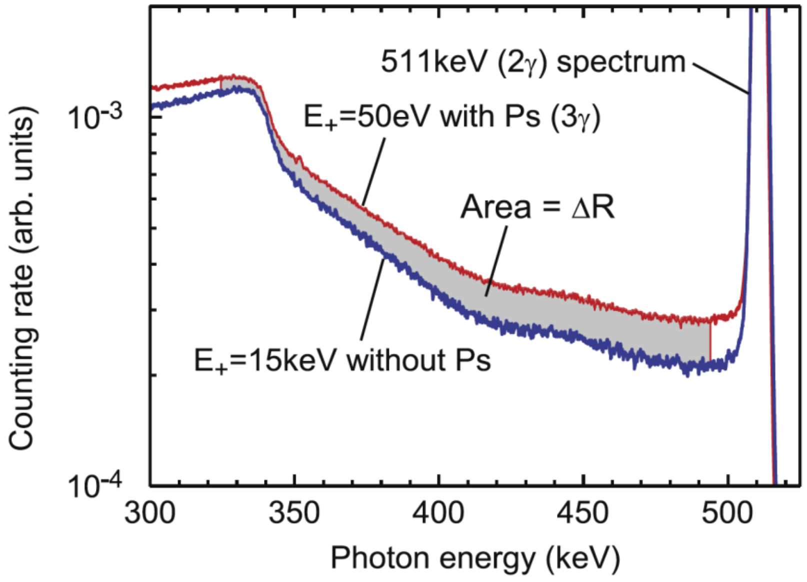
A. Rich, RMP 53 (1981) 127   A. Kawasuso et al., JMMM 342 (2013) 139
B. M. Maekawa et al., JJAP 2 (2014) 011305

- The measurement of the **Doppler broadening** of the **511 keV** pair-annihilation photons can be used to study the **ferromagnetic properties** of materials.



- The measurement of **positronium formation rate** is used to study **current-induced spin polarization** effects (**spintronics**).

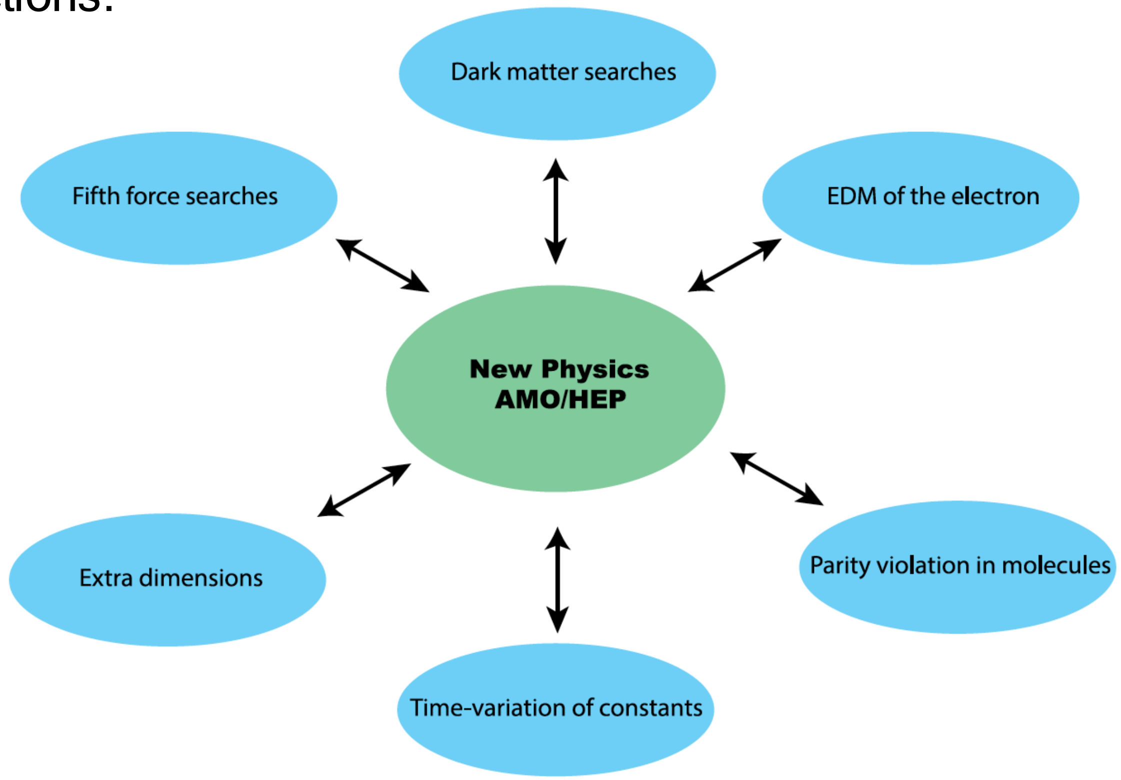




Atomic Physics

G.S. Adkins, D.B. Cassidy, J. Pérez-Rios PR 975 (2022) 1

- As a pure QED system, **positronium spectroscopy** and **decay rates** can serve as a stringent **test** of bound-state **QED theory**.
- The search for **anomalous decay modes** can probe possible violation of C and P symmetries **testing Standard Model** predictions.



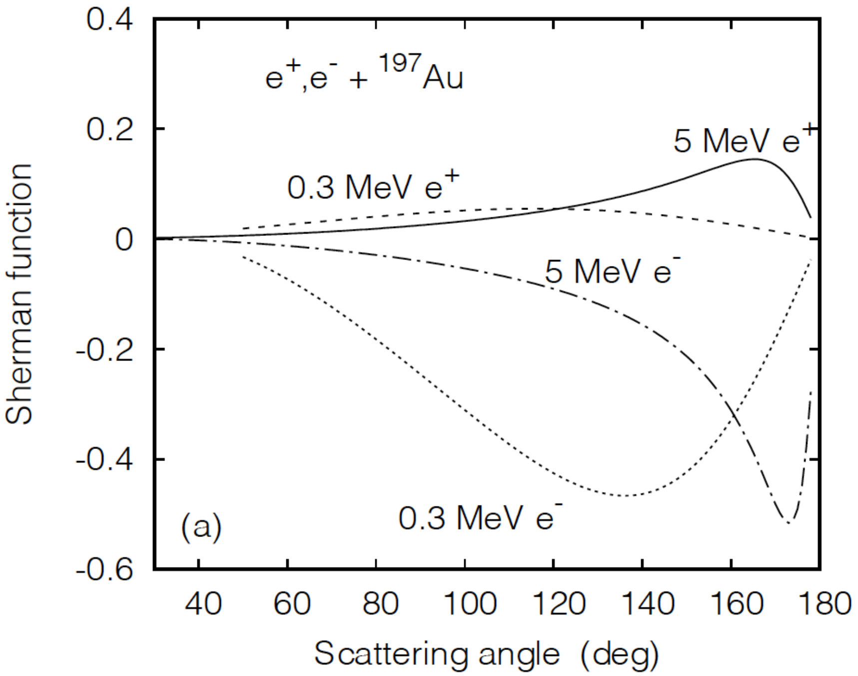
New physics at the interplay between **atomic**, **molecular** and **optical** (AMO) physics and **high-energy** physics (HEP).

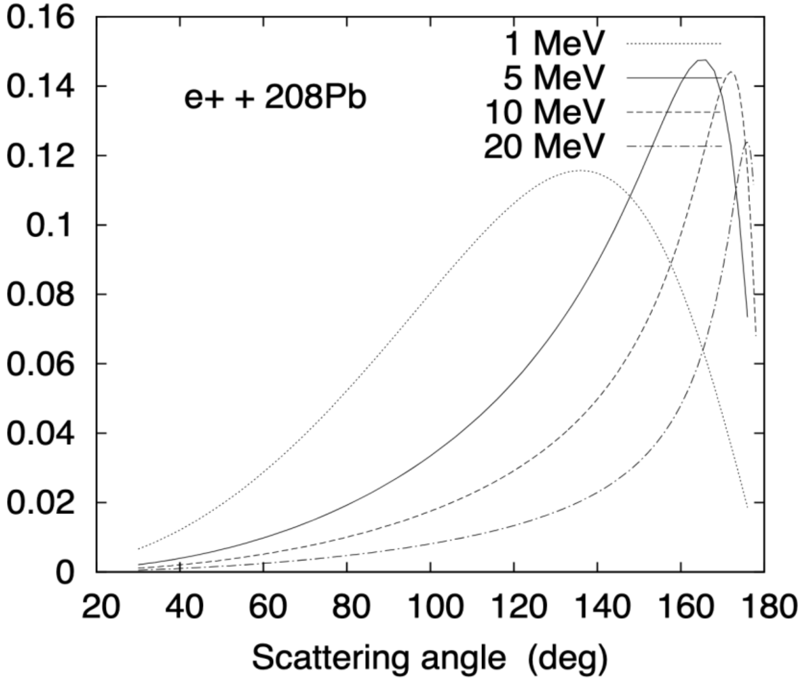
Beam Normal Spin Asymmetry

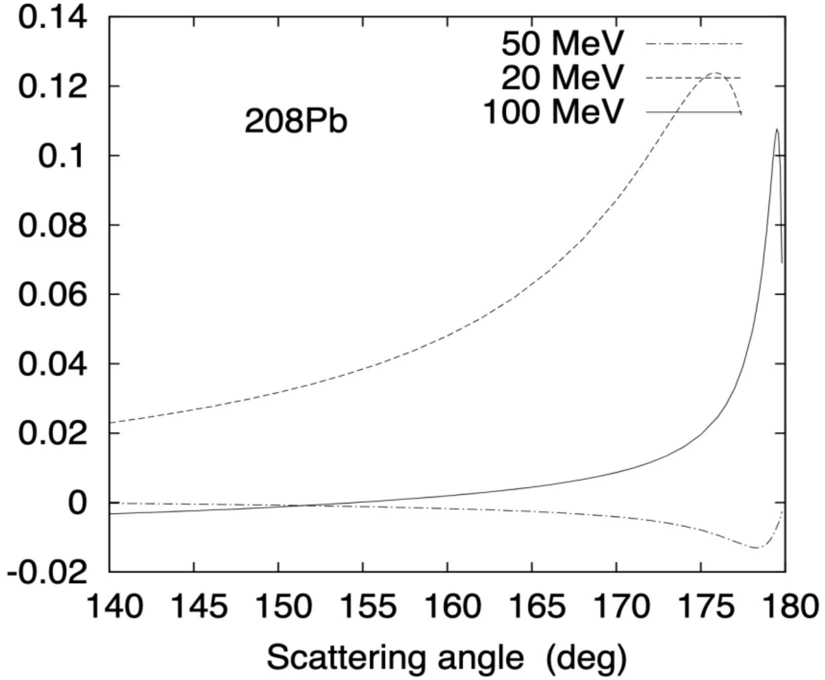
D. Jakubaßa-Amundsen @ HP2030

- **Multi-Photon Exchange** is responsible of the sensivity of the **elastic $e^{\pm}A$ interaction** to the **transverse polarization** of the incoming lepton beam, which is expressed in the **Sherman function**.

- The **5 MeV Mott polarimeter** at the **CEBAF injector** operates according to this principle.







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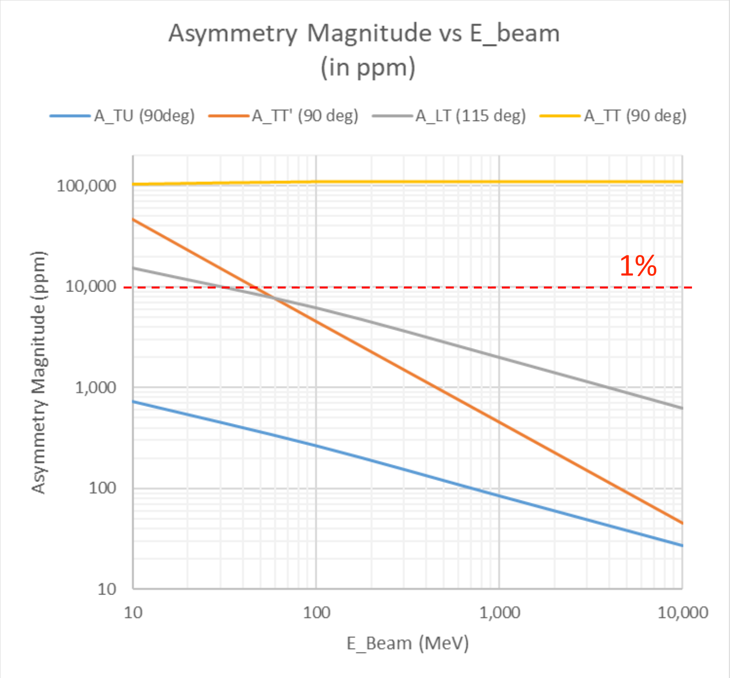
Bhabha Scattering

D. Mack @ HP2030

- As a **pure QED process**, the interpretabilty of **Bhabha scattering** offers the possibilty to search for a **Beyond Standard Model** (BSM) signal by looking at deviations from QED predictions from the **interference between QED and BSM amplitudes**.
- Adding **transverse polarization**, either **beam** or/and **target**, provides access to **never measured double spin observables** testing high order QED effects and potentially interesting for BSM signal search.



- A_{TU} : might be used to test higher order QED effects or to search for the imaginary part of light scalar or tensor novel amplitudes.
- $A_{TT'}$: **optimally sensitive** to the real part of light scalar or tensor novel amplitudes.
- A_{LT} : not particularly sensitive to new (pseudo) scalar interactions but $A_{LT}+A_{TL}$ might be.

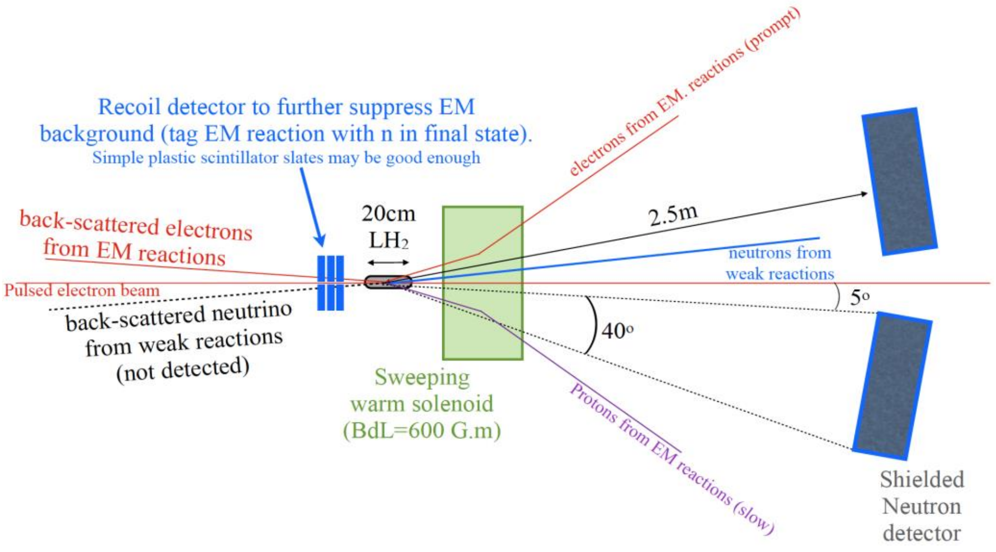
Axial Form Factor

A. Deur @ HP2030

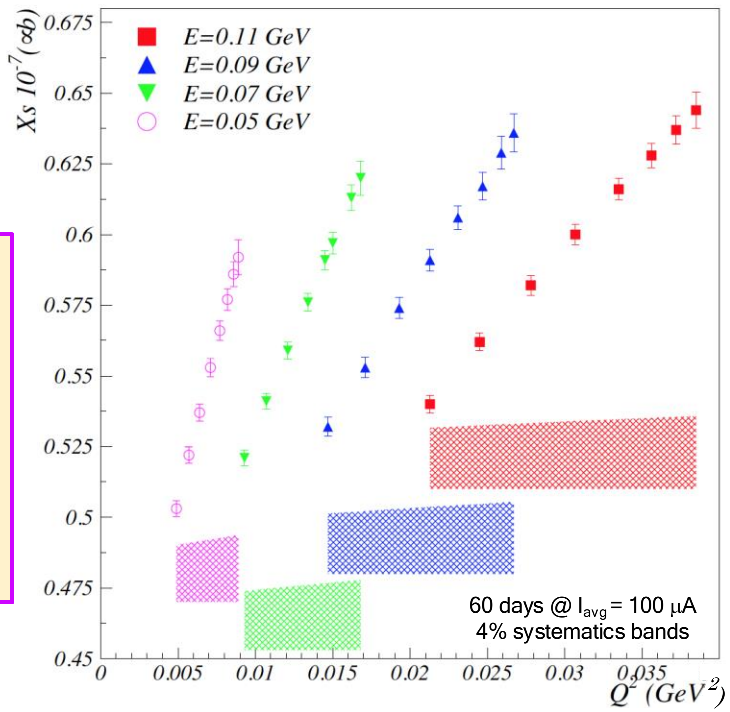
- Taking advantage of a high intensity ($I_e < 1$ mA), highly polarized ($P_e > 80\%$) electron beam with low energy ($T_e < 150$ MeV), the axial form factor $G_A(Q^2)$ of the proton can be measured in **elastic scattering**, that is **inverse β-decay**.
- The experiment does not require new technology but demands a **well-designed detector** and very efficient **background suppression techniques**.

$$\vec{e}^- + p \longrightarrow \mathrm{n} + \nu_e$$

Inverse β-decay is the cleanest access to $G_A(Q^2)$



- **Pulsed** (50 MHz) electron beam
- High efficiency **neutron detector**
- **Sweeping** magnet
- Electron **recoil detector**
- **High purity LH_2** target with **Be windows**



Instrumental Requirements

e^+ Physics @ 10 MeV

- Considering **transverse asymmetries**, the question is about the **required experimental equipments** for such measurements, beyond the 10 MeV electron beam.

e^- Beam

- Polarimeter

e^+ Beam

- Production target
- Collection system
- Momentum selection device
- Beam diagnostics
- Polarimeter
- Spin rotator

Detector

- Reaction targets
- Mott scattering detector
- Bhabha scattering detector

Despite a moderate beam energy,
running an experiment at 10 MeV still requires significant equipment and work force.

Summary

These were a **few examples** of the physics potential of a **low-energy experimental program at LERF**.

There is no doubt that **more possibilities are existing**
(proton magnetic form factor at small Q^2, search for dark photon...)

The JLab PWG
should investigate and enrich its program with these new possibilities.