Future Circular Collider Technical and Financial Feasibility Study
2d FCC Energy Calibration, Polarization and Mono-chromatisation workshop

FCC EPOL WORKSHOP

19-30 September 2022 at CERN

remote participation possible

https://indico.cern.ch/e/EPOL2022

FCC EPOL Workshop Overview

- Primary goal – study energy measurement at a future FCC-ee using resonant depolarization or spin precession
- Workshop took place over a couple weeks
  - 113 registered participants
  - To facilitate remote participation, workshop meetings took place in the afternoon only (CERN time)
  - Mix of plenary and parallel Working Group meetings
  - One goal was to work collaboratively with other accelerators (including EIC) to find areas of common interest/effort
- Working Groups
  - Polarization simulations and spin-tune to beam energy relationship, wigglers and kickers
  - Simulation of the relationship between average beam energy and centre-of-mass energies
  - ***Polarimeter design, performance and integration***
  - Measurements in particle physics experiments
  - Monochromatization

WG3: Polarimeter design, performance and integration Sessions

- Previous and planned polarimeters (overview)
  - EIC (C. Gal), FCC-ee (N. Muchnoi), VEPP (S. Zakharov), HERA (S. Schmitt), SLD (M. Woods), JLab (DG), LEP (J. Wenninger)
- Polarimeter Lasers – technology and diagnostics
  - LUXE diagnostics (G. Sarri), HERA LPOL2 (F. Zomer), SuperKEKB, ILC (A. Martens), CERN operational experience (B. Marsh, E. Granados), JLab and EIC (C. Gal), EIC integration (Z. Zhang)
- Polarimeter Detectors
  - JLab lessons learned (A. Camsonne), ILC (J. List), SuperKEKB (A. Martens), LUXe (L. Helary), L4 emittance meter (A. Goldblatt, F. Roncarolo), LHC Lumi. Monitors (S. Mazzoni), Timpix3-based detectors (J. Storey), EIC detectors (J. Fast)
- Backgrounds
  - JLab (DG), SuperKEKB (H. Nakayama), EIC backgrounds (C. Gal), Detector Integration at EIC (Z. Zhang)

HERA LPOL2 laser system and polarization control

Fabian Zomer
HERA LPOL2 made extensive measurements to constrain the laser polarization to better than 0.1%

→ Key issue is imperfections in quarter-wave plate used in laser polarimeter
→ Took much effort to measure, model QWP

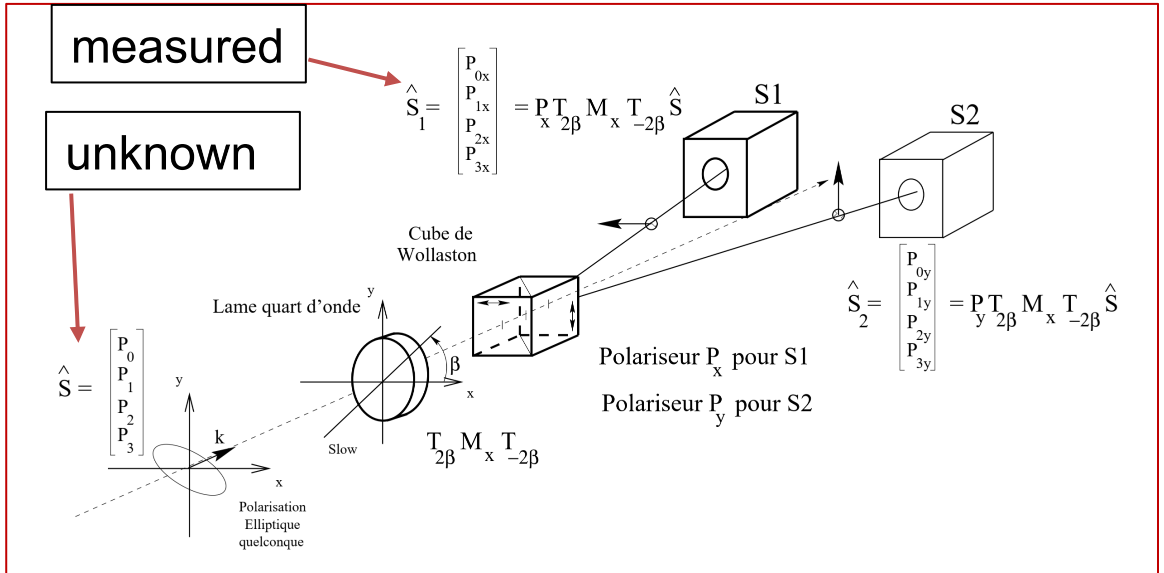
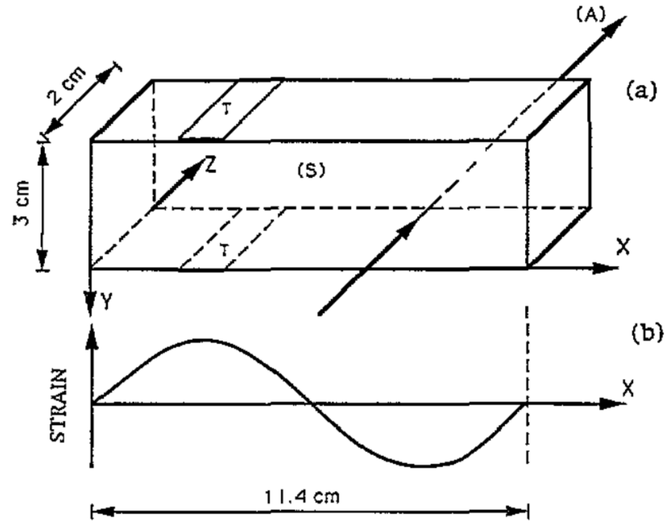


FIG. 4.12 - *Mesure de la polarisation sur le montage de TJNAF.*



Proposed improvement → use photo-elastic modulator instead of QWP
→ Rapid modulation – automated calibration? (R&D in progress)

Some discussion after talk about using back-reflected light technique planned for EIC

An idea for SuperKEKB photon detector

Aurélien Martens

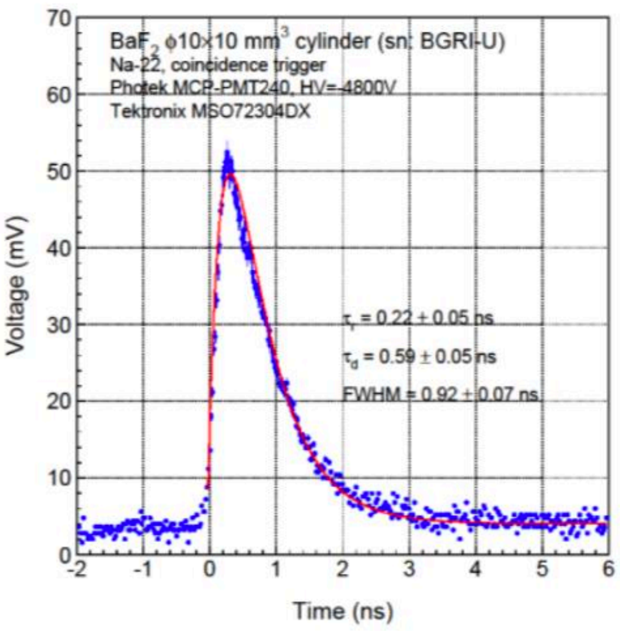
SuperKEKB similar operating mode as EIC
→ 250 MHz repetition rate (4 ns spacing)
→ 7 GeV beam energy
→ Expected dose in detector O(1MGy/year) (1GeV@250MHz)

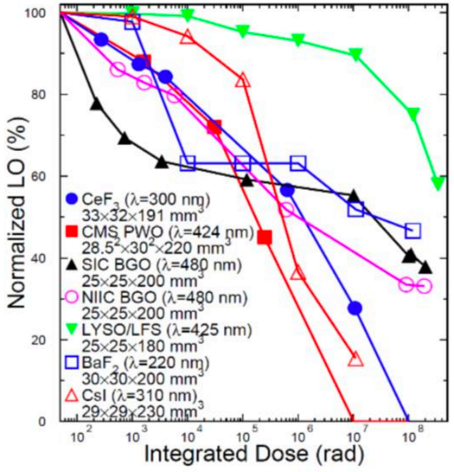
We have discussed lead-tungstate, but not BaF2
→ Resolution a little worse, but still pretty good

Basic idea of detector

Basic elements

- a VERY FAST radhard scintillating crystal → BaF2
  - Need to filter out the slow component → UV optical filters
  - Interesting: Y doping reduces the slow component, but R&D stage
- a PMT with low transit time dispersion → commercially available (hamamatsu for instance)
- Associated electronics
- Next step: validate detection scheme





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Ultrafast and Radiation Hard Inorganic Scintillators for Future HEP Experiments

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Abstract. Future HEP experiments at the energy and intensity frontiers require fast and ultrafast inorganic scintillators with excellent radiation hardness to face the challenges of unprecedented event rate and severe radiation environment. This paper reports recent progresses in fast and ultrafast inorganic scintillators, such as LYSO:Ce crystals and LuAG:Ce ceramics for an inorganic scintillator based shashlik sampling calorimeter and yttrium doped BaF_2 crystals for the proposed Mu2e-II experiment. Applications of ultrafast inorganic scintillators in Gigahertz hard X-ray imaging will also be discussed.

1. Introduction

Inorganic scintillators have been used widely in high energy and nuclear physics experiments, medical instruments and homeland security applications. In high energy physics (HEP) and nuclear physics experiments, total absorption electromagnetic calorimeters made of inorganic crystals are known for their superb energy resolution and detection efficiency for photon and electron measurements [1]. An inorganic crystal calorimeter is thus the choice for those experiments where precision measurements of photons and electrons are crucial for their physics missions.

Among all existing crystal calorimeters, the CMS lead tungstate (PbWO4 or PWO) crystal calorimeter, consisting of 75,848 crystals of 11 m^3, is the largest. Because of its superb energy resolution and detection efficiency, the CMS PWO calorimeter has played an important role for the discovery of the Higgs boson by the CMS experiment [2]. Crystal calorimeters currently under construction are: an undoped CsI calorimeter for the Mu2e experiment at Fermilab, a PWO calorimeter for PANDA at FAIR, a LYSO calorimeter for COMET at JPARC and a PbF_2 calorimeter the g-2 experiment at Fermilab.

Future HEP calorimeters will be operated under unprecedented luminosity. An important issue is thus the decay time of scintillation light. Table 1 lists the optical and scintillation properties for fast inorganic crystal scintillators with a scintillation decay time ranged from sub-nanosecond to a few tens nanosecond, and compared to plastic scintillator [1]. Among the fast crystals listed in Table 1 the mass-production cost of barium fluoride (BaF_2) and undoped CsI crystals is significantly lower than others because of their low raw material cost and low melting point.

Crystal calorimeters for future HEP experiments at the energy frontier face a challenge of severe radiation environment. Significant losses of light output have been observed in the CMS PWO crystals at large rapidity *in situ* at the LHC caused by both ionization dose and hadrons [3]. Controlling oxygen contamination in halide crystals, e.g. CsI:Tl, or oxygen vacancies in oxide crystals, e.g. PWO, was found effective [4]. Co-doping with yttrium and lanthanum was also found effective for CMS PWO crystals [5]. For experiments to be operated at the HL-LHC with 3,000 fb^{-1}, crystals should survive an environment with an absorbed dose of 100 Mrad, charged hadron fluence of 6×10^{14} p cm^{-2} and fast

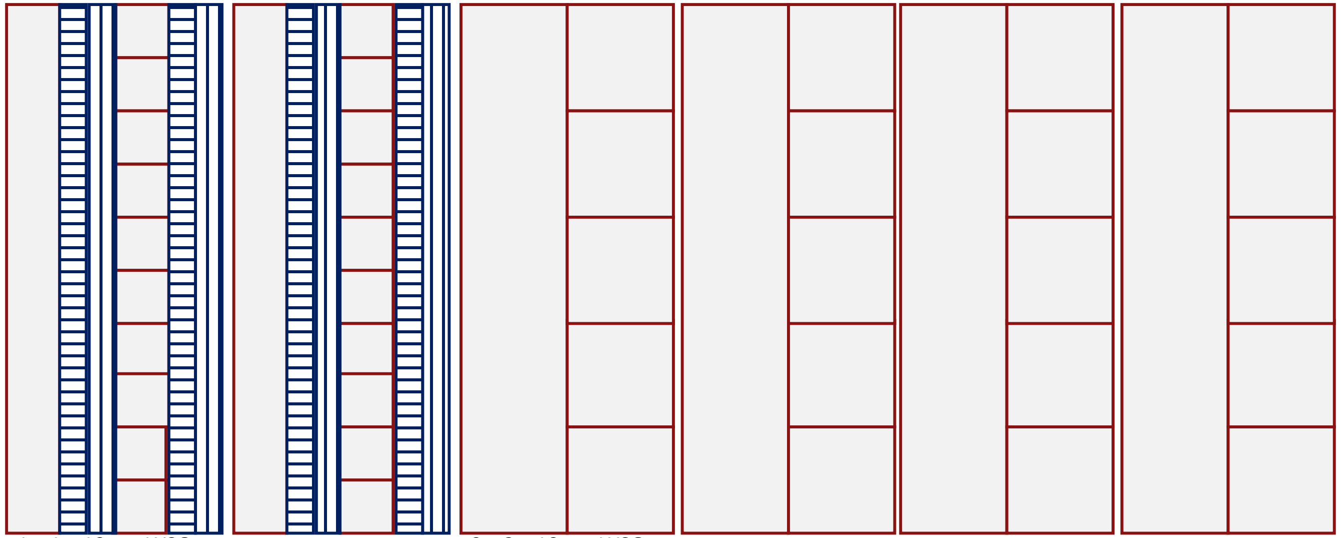
Compton Polarimeter Detectors for the EIC

Some conceptual ideas – Jim Fast

ASICS for position sensitive (diamond) detectors
- → FLAT-32 (under development by SenseIC) – higher density Calypso chip
- → SAMPA (developed for ALICE TPC) – JLab building test board for use with diamond
- → VMM3 (designed for ATLAS MPGD) – viable for diamond
- → SALT 3 (developed for LHCb VELO silicon) – likely not adequate, can't get them anyway

Photon calorimeter ideas
- → Use detector crystals as active pre-radiator for position detectors
- → Optimizes energy resolution, higher efficiency for strip detectors

Crystals
- → New results on PbWO4: arXiv:2103.13106v2 (2 ns fast component, 6 ns slow component)
- → $CeBr_3$ (19 ns) , LYSO:Ce (36 ns), BaF_2:Y (0.5 ns @ 220 nm)



Backgrounds at SuperKEKB/Belle-II

Hiroyuki Nakayama

Sources of background:

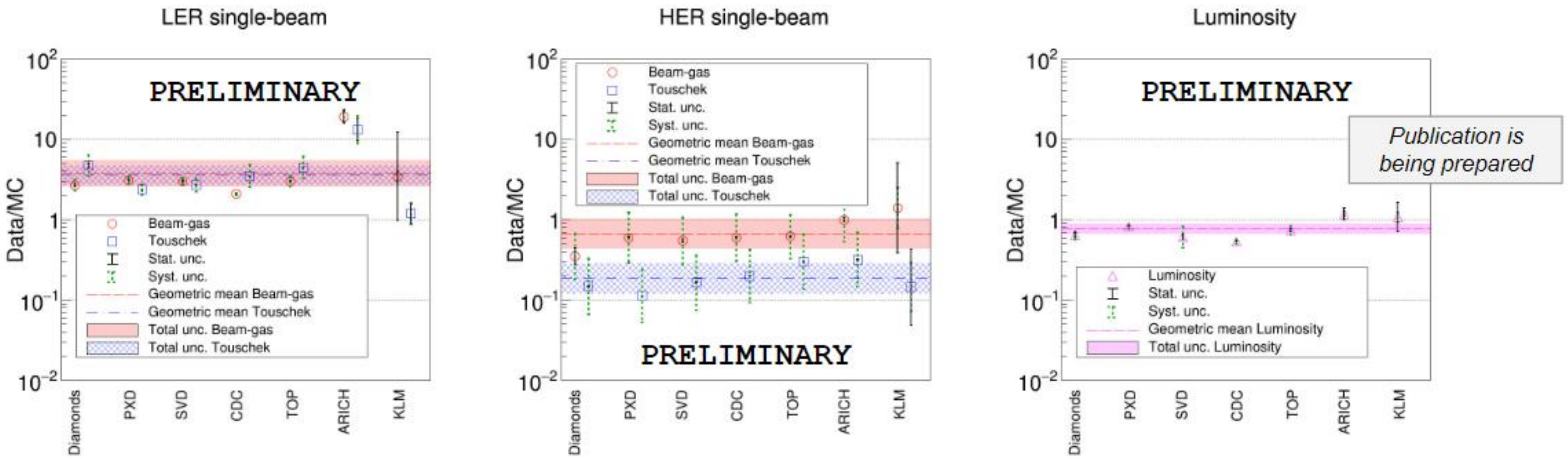
- *Single-beam BG*: Touschek, Beam-gas Coulomb/Bremsstrahlung, Synchrotron radiation, injection BG
- *Luminosity BG*: Radiative Bhabha, two-photon BG, etc..

Beam background mitigation via movable collimators and tungsten shielding at main beam loss points near detector

- 31 movable collimators
- Gradual reduction in background over 1+ year
- Original final focusing quad design - no room for shielding. Had to redesign once background simulations became more mature
- Extensive background measurements – allow comparison with detailed simulation

Instabilities in initial injection of top-off bunches lead to significant backgrounds

Ratios of measured (**data**) to simulated (**MC**) backgrounds based on dedicated studies in 2020-2021



EIC and FCC – Areas of Common Interest

- Laser systems and diagnostics
  - Precision seems to be a key requirement for FCC – knowledge of laser polarization will be important
- Detector systems
  - Measurement of pilot bunches perhaps not too challenging, but measurement of colliding bunches (25 MHz) could pose similar timing challenges as EIC
- Backgrounds
- Beamline integration
- Software – simulation
  - FCC at the moment only has a toy Monte Carlo to look at rates etc. Has expressed interest in working with the EIC Compton G4 MC