VMBCERN: Vacuum Magnetic Birefringence at CERN

H. Euler and B. Kockel (1935): effective Lagrangian density describing non-linear electromagnetic interactions in the presence of the virtual electron-positron sea proposed a few years before by Dirac:

$$\mathcal{L}_{EK} = \frac{1}{2\mu_0}\left(\frac{E^2}{c^2} - B^2\right) + \frac{A_e}{\mu_0}\left[\left(\frac{E^2}{c^2} - B^2\right)^2 + 7\left(\frac{\mathbf{E}}{c}\cdot\mathbf{B}\right)^2\right] + \ldots$$

$$A_e = \frac{2}{45\mu_0}\frac{\alpha^2\hbar^3}{m_e^4 c^5} = 1.32 \times 10^{-24}\ \mathrm{T}^{-2}$$

Light propagation in vacuum is still described by Maxwell's equations in materials

but these are no longer linear due to Euler-Kockel correction:

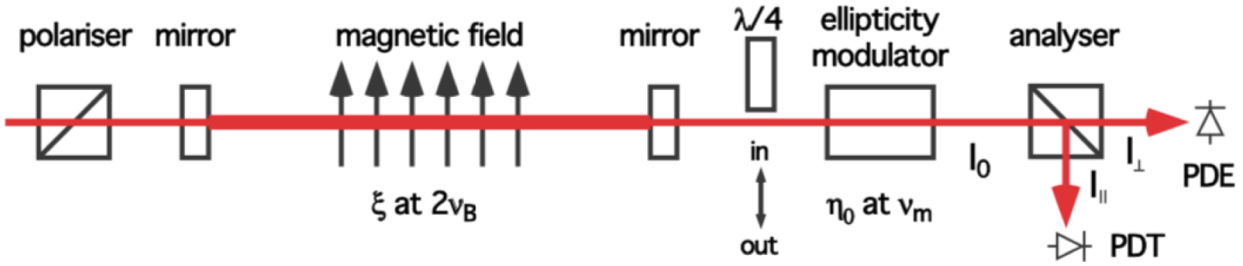
The superposition principle no longer holds

n > 1 in vacuum

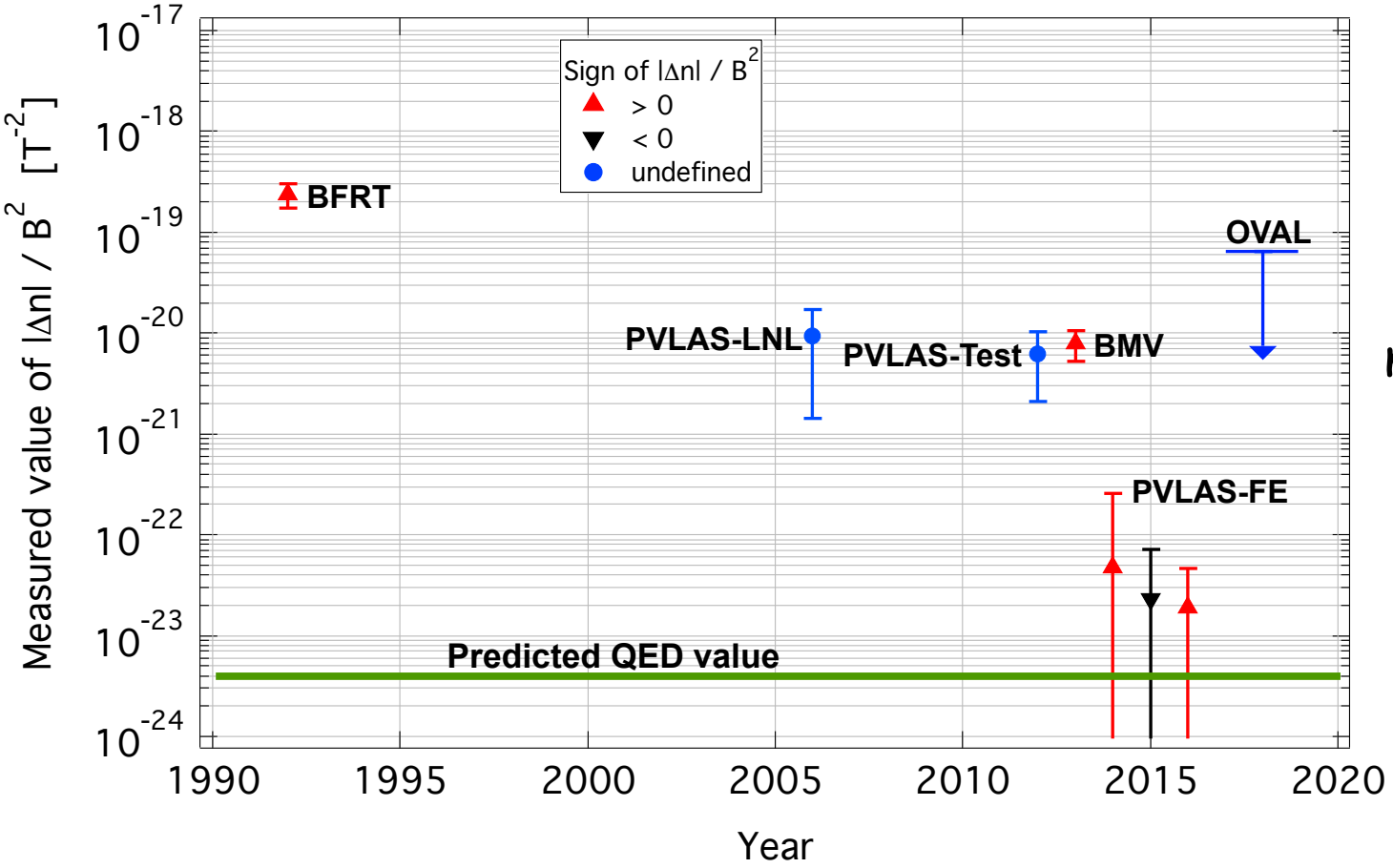
$$n_{\parallel}^{(\mathrm{EK})} = 1 + 7A_e B_{\mathrm{ext}}^2 \qquad n_{\perp}^{(\mathrm{EK})} = 1 + 4A_e B_{\mathrm{ext}}^2$$

$$\Delta n_B = 2.5 \times 10^{-23} \quad @ \quad 2.5\ \mathrm{T}$$

State of the art: the PVLAS experiment



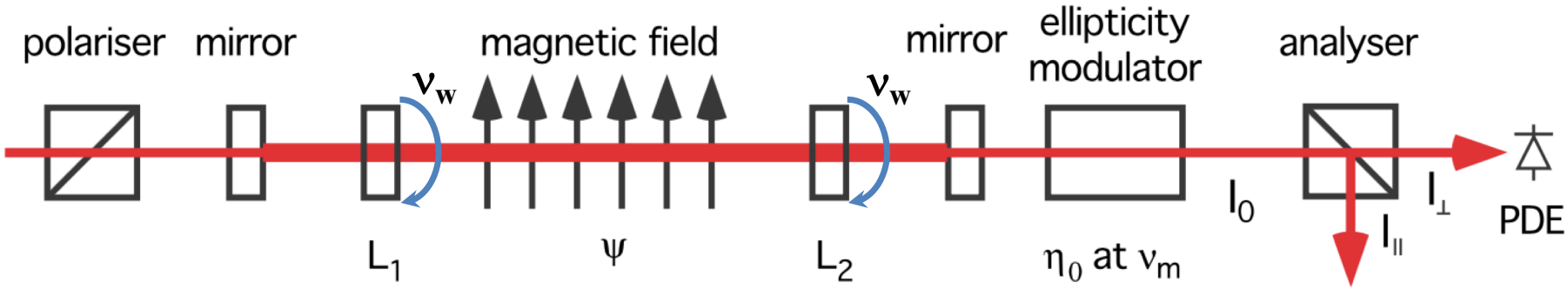
Ellipticity measurement from the Fourier transform of the extinguished intensity



Limited by intrinsic excess noise coming from the Fabry-Perot cavity mirrors

VMBCERN: new polarimetric scheme

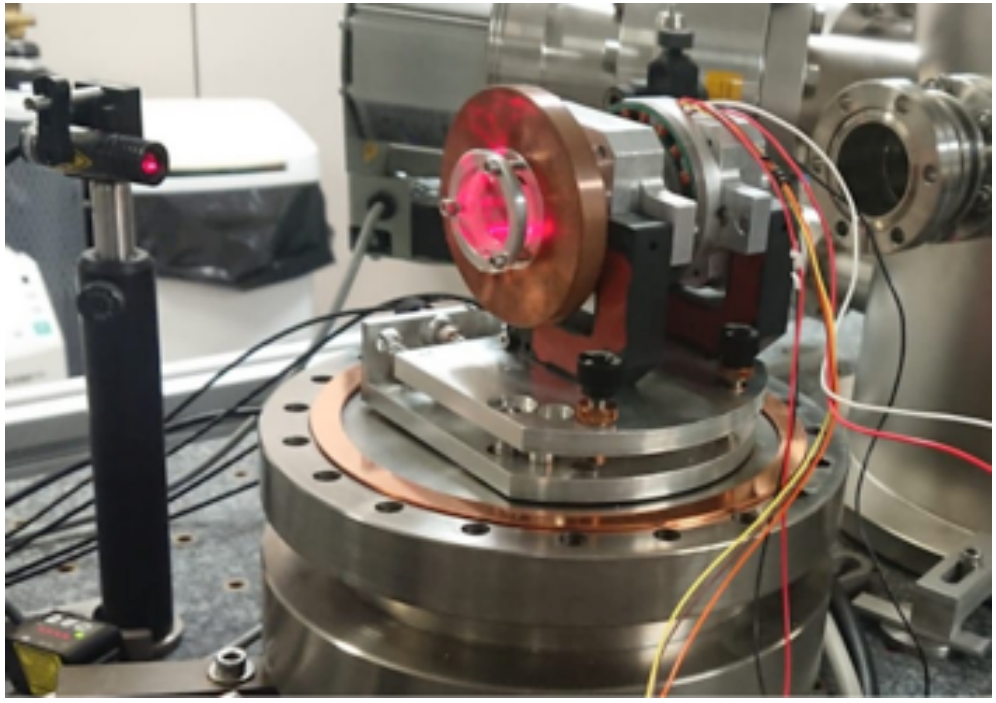
- Increase signal: employ a spare LHC magnet
- Two half-wave plates co-rotating @ ν_{HWP} with a fixed relative angle $\Delta\phi$
- Polarization rotates inside the magnetic field, whereas it is fixed on the mirrors to avoid mirrors birefringence signal
- Effect appears at $4\,\nu_{HWP}$
- Low finesse cavity → shot noise
- At shot noise measurement time is only 1 day
- Use **two** wavelengths (infrared and green) to study the defects of the waveplates



G Zavattini et al, EPJC **76**, 294 (2016)

VMBCERN: June 2021 status

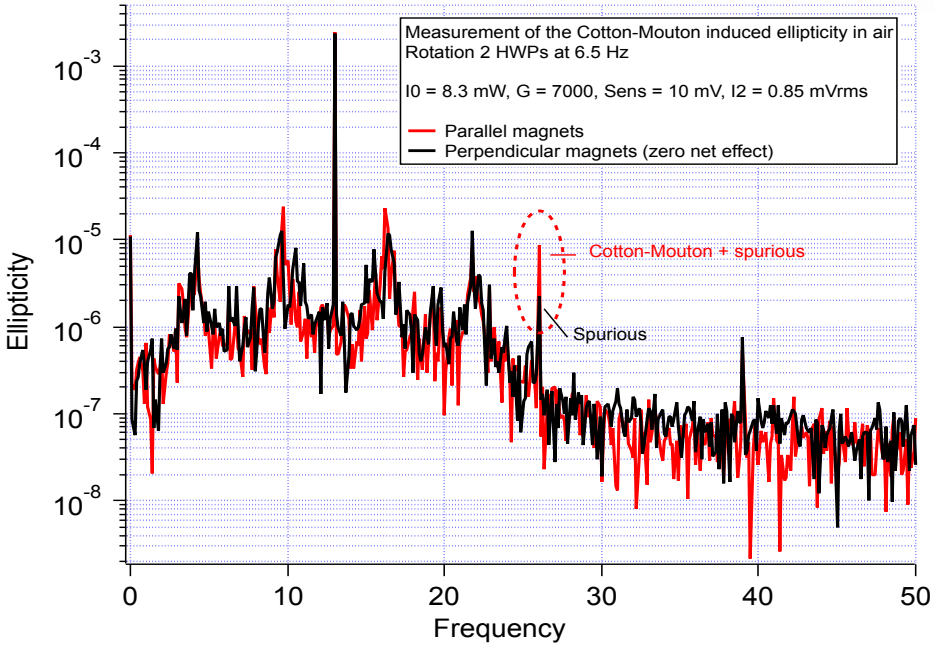
- Realized two prototype rotators with 4-degrees of freedom alignment capabilities and ν_{HWP} up to ~12 Hz

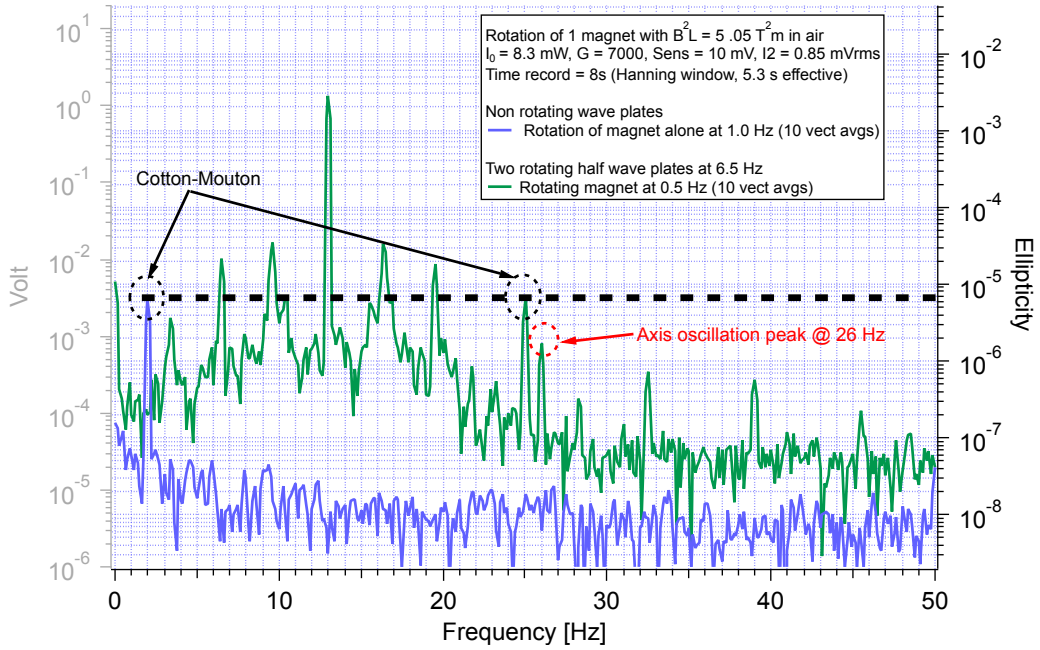


- Polarimetric method tested with the Cotton Mouton effect in air and in a pure gas using the dipole magnets of the PVLAS experiment
- Fabry-Perot cavity not installed yet
- Green laser not installed yet

VMBCERN: 2021 status: open problems

A spurious effect appears at the signal frequency due to in-phase oscillation of the rotation axis





Possible workaround: separate signal from the spurious by modulating the magnetic field at low frequency

How fast can we ramp the CERN magnet?

Which is the line-width of the spurious peak?

VMBCERN: 2021 status: open problems - 2

Dynamical relative rotation errors (~ 1°) between the two rotators limit extinction and hence sensitivity.

Possible workarounds:

- better extinction with a Faraday rotator in a closed loop feedback
- realize more precise rotators (encoders, stepper motors, etc.)

Per il 2022 chiediamo un'estensione dell'esperimento pilota:

- **messa in opera del rotatore Faraday (2021)**
- **installazione del laser verde per studiare i sistematici (2021)**
- **progetto e realizzazione di nuovi rotatori per le lamine**
- **installazione della cavità Fabry-Perot**

Contributo di Siena: progetto e realizzazione di prototipi di sistemi di rotazione con controllo di quattro gradi di libertà

VMBCERN: numeri 2022

10 Ricercatori – 5.0 FTE

Ferrara:	M. Andreotti	10%
	P. Cardarelli	20%
	G. Di Domenico	40%
	G. Zavattini	**70% Resp. Naz.**
	G. Messineo	100% (Fellini)
LNL:	R. Pengo	40%
	G. Ruoso	40%
Pisa (Siena):	**F. Della Valle**	**100%**
	C. Marinelli	40%
	E. Mariotti	40%

Richieste finanziarie Pisa 18 k€

Missioni	12 k€ (10 k€ missioni di lavoro + 2 k€ conferenze)
Consumo	6 K€

Nessuna richiesta di servizi alla Sezione