Heavy Scintillating Crystal Fibers for calorimetry

E. Auffray, P. Lecoq, CERN, Geneva

Proposal

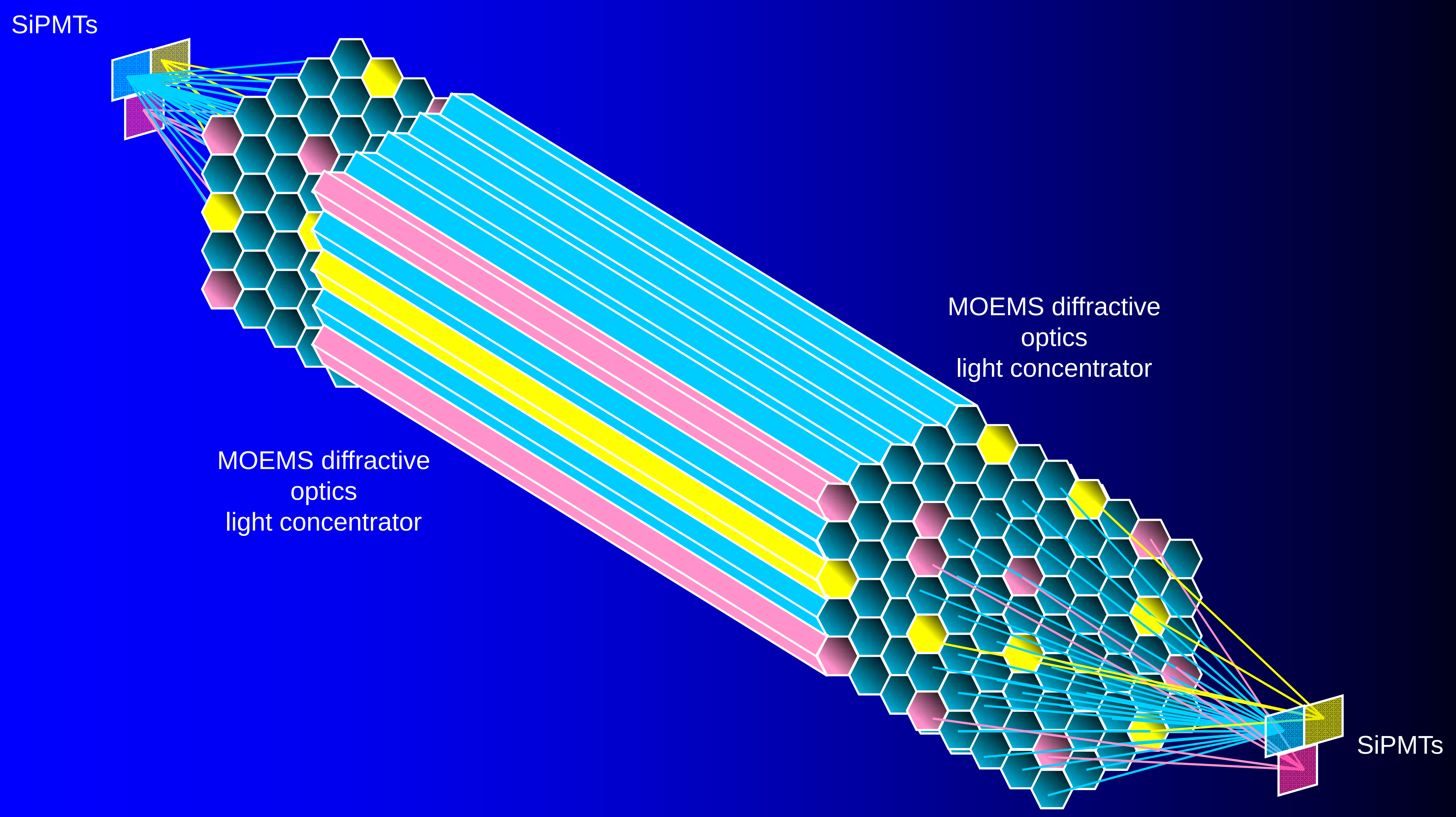
- New technologies in the production of heavy scintillators open interesting perspectives for calorimetry in future colliders :
  - Design flexibility: detector granularity
  - Functionality: extract more information than simple energy deposit

- The concept of this proposal is based on metamaterials with dual/triple readout capability
  - Scintillating cables made of heavy scintillating fibers of different composition ⇨ quasi-homogeneous calorimeter
  - Fiber arrangement in such a way as to obtain 3D imaging capability
  - Fiber composition to access the different components of the shower

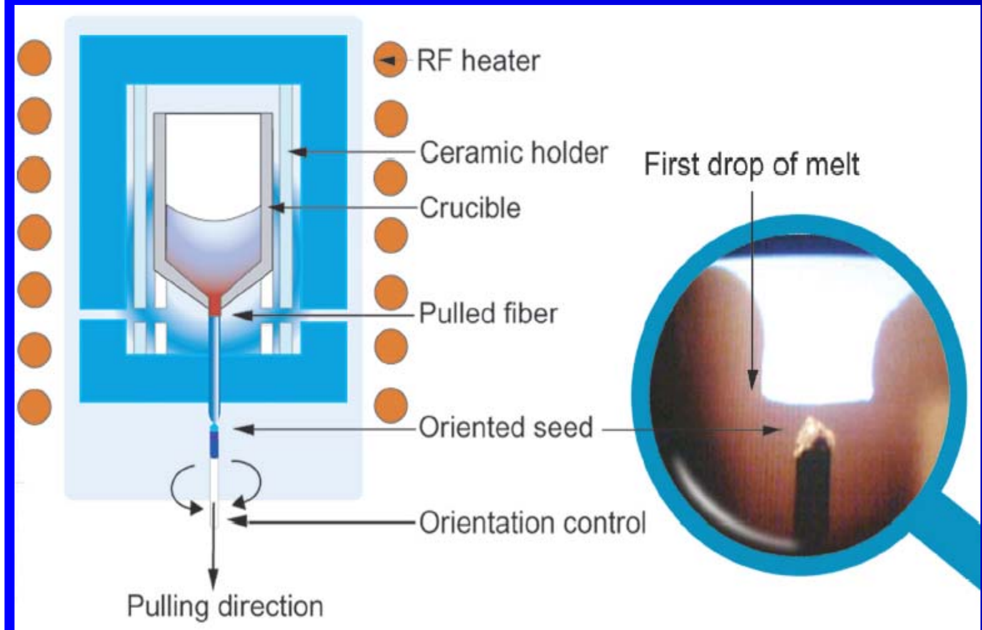
Concept of meta-cable

- Select a non-intrinsic scintillating material (unlike BGO or PWO) with high bandgap for low UV absorption
- The undoped host will behave as an efficient Cerenkov: heavy material, high refraction index n, high UV transmission
- Cerium or Praesodinum doped host will act as an efficient and fast scintillator
  - ≈ 40ns decay for Ce
  - ≈ 20ns decay for Pr
- If needed fibers from neutron sensitive materials can be added:
  - Li Tetraborate: $Li_2B_4O_6$
  - LiCaF: $LiCaAlF_6$
  - elpasolite family (Li or B halide of Rb, Sc and rare earth)
- All fibers can be twisted in a cable behaving as a pseudo-homogeneous active absorber with good position and energy resolution and particle identification capability
- Readout on both sides by SiPMT's

Concept of a Meta-cable for HEP



Micro-pulling-down crystal fiber growth

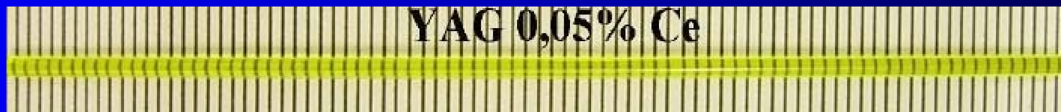


Crucible and fiber

BGO

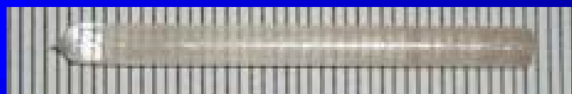
Φ=400µm

YAG:Ce



Φ=1mm

LYSO:Ce



Φ=2mm

YAP:Ce

Φ=2mm

Courtesy Fibercryst, Lyon

Lutetium Aluminum Garnet
LuAG ($Lu_3Al_5O_{12}$)

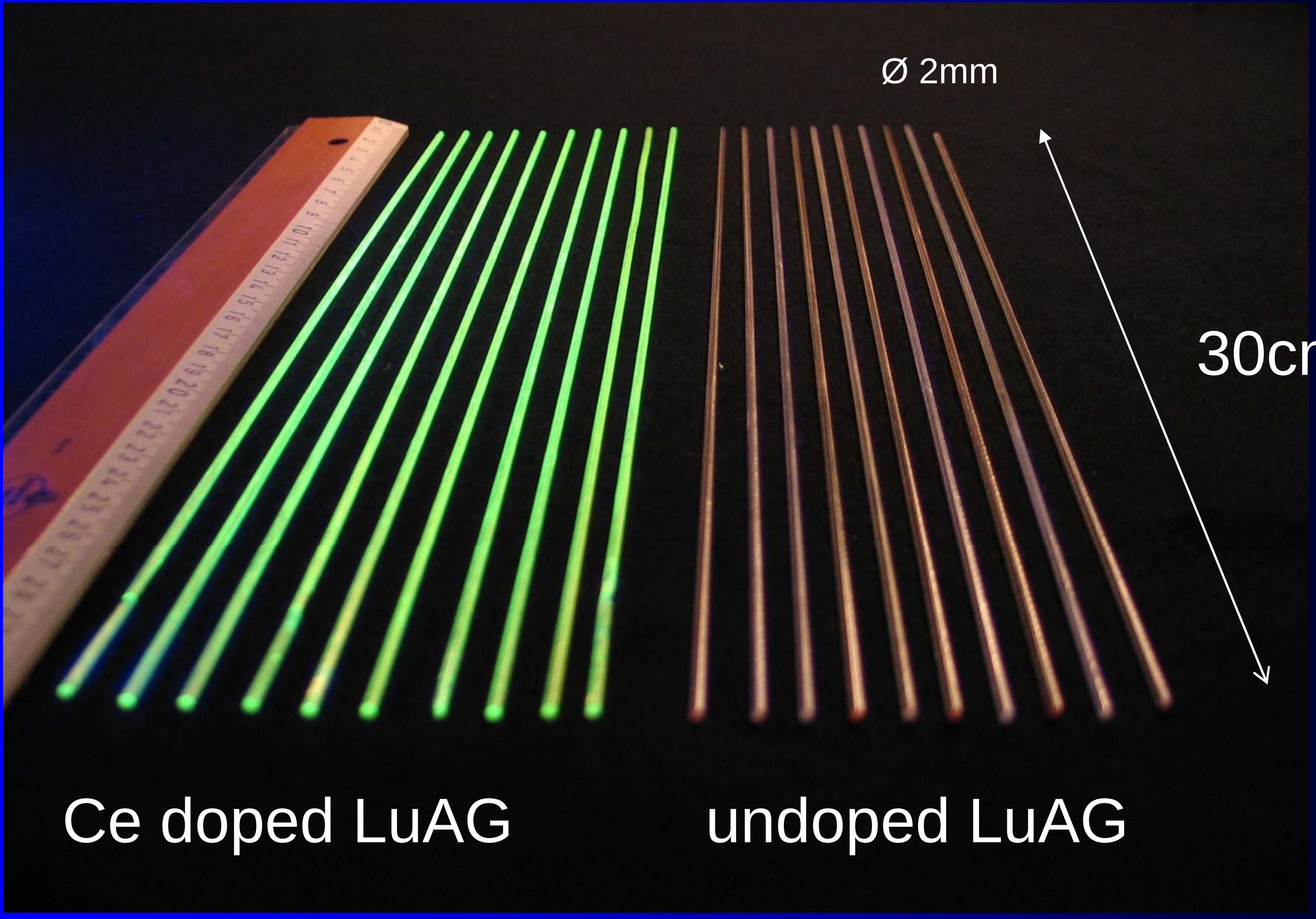
Physico-chemical properties

Structure / Space group	Cubic / Ia3d
Density (g/cm^3)	6.73
Zeff	62.9
Radiation length X_0 (cm)	1.41
Interaction length (cm)	23.3 *LuAP: 19.8* *Fe: 17*
Hardness (Mohs)	7.5 *PWO: 3* *BGO, glass: 5*
Fracture toughness ($Mpa.m^{1/2}$)	1.1
Cleavage plane / H_2O solubility	No / No
Melting point (°C)	2260
Thermal expansion @ RT ($°K^{-1}$)	$8.8\ 10^{-6}$
Thermal conductivity @ RT (W/m°K)	31

Optical properties

Light yield: Ce or Pr doped (ph/MeV)	20'000 *1/2 NaI(Tl)*
d(LY)/dT	?
Emission wavelength (nm): Ce doped Pr doped	535 290, 350
Decay time (ns): Ce doped Pr doped	70 20
Refractive index @ 633nm (isotropic) $n^2 = 3.3275151 - 0.0149248\ \lambda^2$	1.842 *Quartz: 1.55*
Fundamental absorption undoped (nm)	250
Max. Cerenkov 1/2 angle	57°
Total reflexion 1/2 angle	33°
Cerenkov threshold e energy (KeV)	97

1st fibres received in Sept08



Status of the development

- Optical characterisation
(Attenuation, Light Yield, Decay time)
- Test readout with SiPMT and diffractive optics
- Material optimisation in Collaboration with Company
- Preparation of new test beam for 2009 with bigger cable (size comparable to a CMS PWO crystal (2x2x23cm)
- Simulation studies to determine and optimise the detector geometry and granularity needed for a precise determination of the electromagnetic fraction of the energy deposition in jets both at SHLC in the forward region and at CLIC energies.