SCINTILLATING FIBER CHOICE INTRO

MARIA ŻUREK

ZISIS PAPANDREOU

HENRY KLEST

CONSIDERATIONS

- How many photons do we see at the SiPM?
  - Raw yield of photons / MeV
  - Attenuation length
  - Cladding for better light trapping
  - Wavelength of photons emitted at the end of the fiber
- Scintillation process timing characteristics
- Cost, schedule, delivery method
  - Delivered in canes or spools?
  - 4500 km of fibers, non-trivial logistics
- Options on the table are Kuraray single- and double-clad, as well as Luxium single-clad (double-clad??)

FIBER SPECS

- All three fiber options have similar scintillation yields of ~8000 photons/MeV
  - Emission spectra well matched to SiPM PDE curve
- Differences in trapping efficiency, attenuation, cost

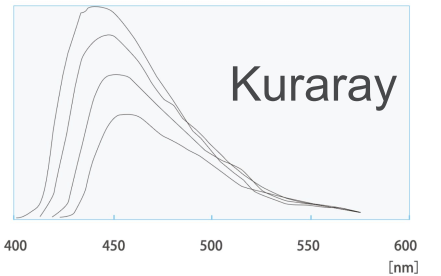
Attenuation

- Fairly vague information given on attenuation by manufacturers
- Measurements performed by Regina & Korea
- Simulation studies by Maria

Luxium

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	# of Photons per MeV*	Attenuation Length (m)**	Characteristics / Applications
BCF-10XL	blue	432	2.7	~8000	>4	General purpose; optimized for diameters >250µm

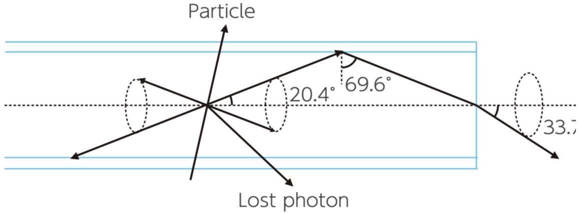
SCSF-78



Description	Emission			Decay Time [ns]	Att.Leng.[2] [m]	Characteristics
	Color	Spectra	Peak[nm]			
SCSF-78	blue		450	2.8	>4.0	Long Att. Length and High Light Yield

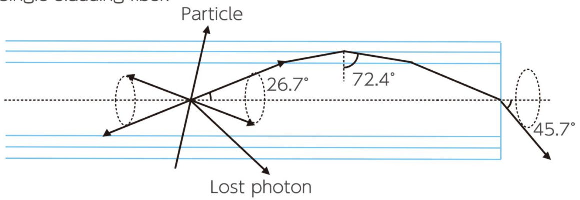
Single cladding

Single cladding fiber is standard type of cladding.



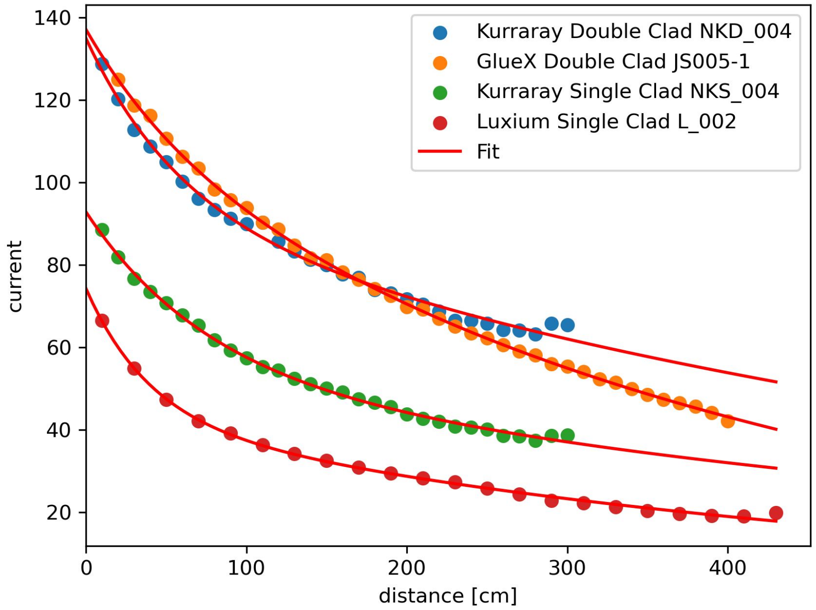
Multi-cladding

Multi-cladding fiber(M) has higher light yield than single cladding fiber because of large trapping efficiency.
Clear-PS fiber of this cladding has extremely higher NA than conventional PMMA or PS fiber, and very useful as light guide fiber.
Multi-cladding fiber has long attenuation length equal to single cladding fiber.



SciFi studies - Input

Measured attenuation dependencies for different naked fibers measured



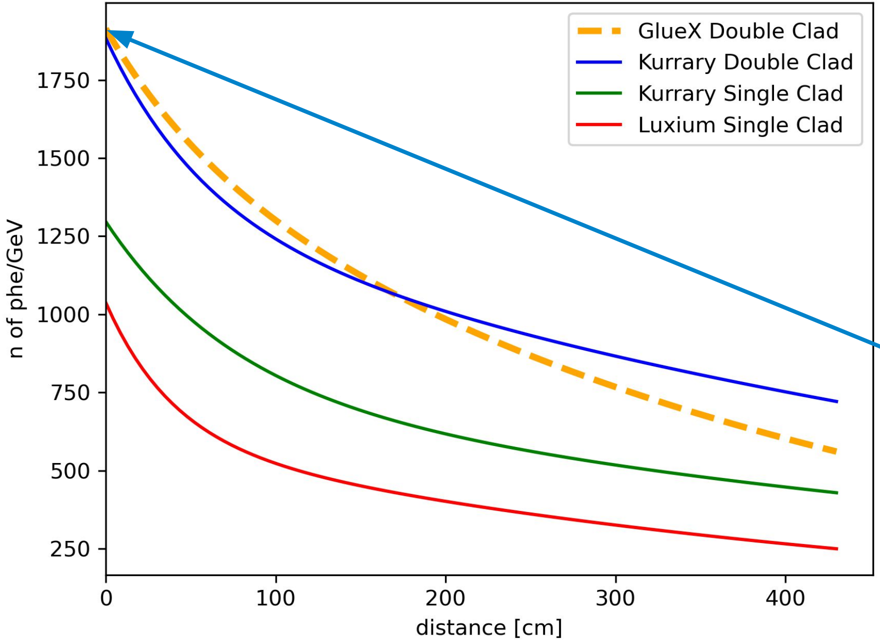
From measurements at Uni Regina

$$I(\Delta) = I_0(\alpha e^{\Delta/\lambda_1} + (1-\alpha)e^{\Delta/\lambda_2})$$

	I_0	α	λ_1 [cm]	λ_2 [cm]
Kuraray Single Clad	9.29E+01	4.16E-01	7.47E+01	7.52E+02
Kuraray Double Clad (New)	1.35E+02	3.06E-01	5.82E+01	7.23E+02
Luxium Single Clad	7.43E+01	4.23E-01	3.92E+01	4.91E+02
GlueX Kuraray Double Clad	1.37E+02	1.81E-01	6.09E+01	4.18E+02

SciFi studies - Input

N of phe/GeV for different fiber types



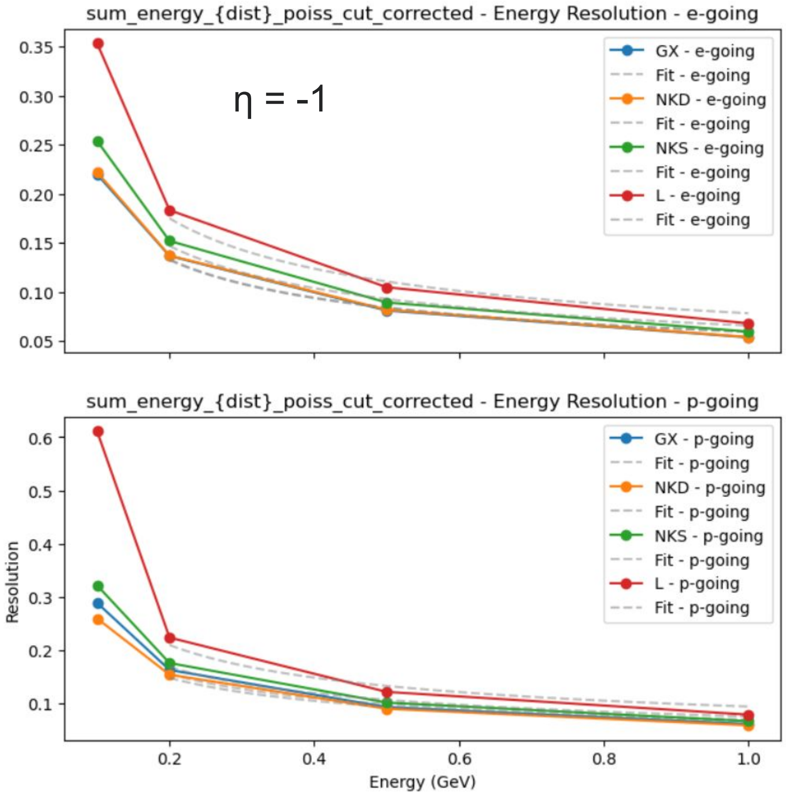
- Nb of photelectrons/GeV corrected for attenuation from Baby BCal Hall D measurement [phe/GeV]: **1100**
  - Improvement factor from new family SiPMs from improvement in PDE: **1.5**
  - Improvement factor from optical connection: **1.16**
- Attenuation dependence from Old Kuraray Fiber (GlueX Double Clad) anchored to 1914 phe/GeV at d = 0 cm

SciFi studies - 2-side readout

Use attenuation dependencies (nphe/GeV) to calculate energy and nphe per side of SciFi/Pb Calo

- From the simulation: energy per calorimeter cell: E^{cell}, and z position of the shower (that gives us *dist1* and *dist2*)
- **E^{cell} is translated to *nphe* per end** of the calorimeter (at *dist1*, and *dist2*) using attenuation dependencies
- *nphe* at each end of the calorimeter **rounded** to integer, and **smeared with Poissonian distribution**
- After smearing, ***nphe* are translated to energy** at each calo end, and energy **threshold cut (5 MeV or nb of phe, i.e., 5 phe) is applied**
- Energies of the cells that survived the cut are then **corrected back for attenuation and summed** → this gives us "calibrated for attenuation" energy per side of the calorimeter
  - Final absolute calibration requires adjustment of the sampling fraction/calibration constant to match the true particle energy

Low Energy Gammas - Energy Resolution

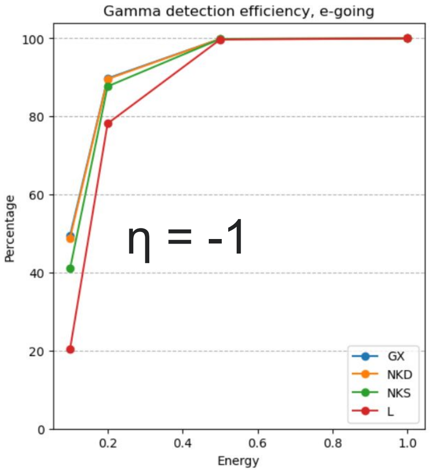


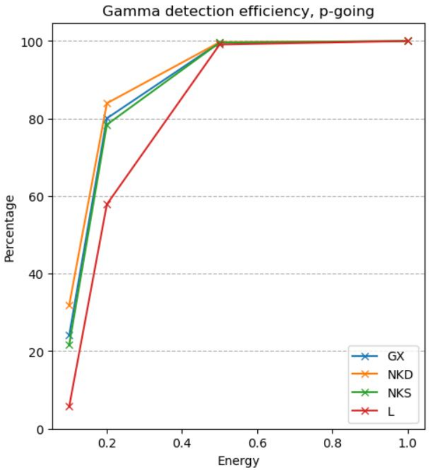
Low energy points with minimum energy cuts (5 MeV corrected for sampling fraction, ~0.5 MeV for non-corrected energy)

	e-going	
	a	**b**
Old GX	0.059(0.0045)	7.5e-09(3.9e+04)
NKD	0.06(0.0044)	8.6e-09(3.5e+04)
NKS	0.066(0.0054)	4.2e-09(6.5e+04)
L	0.078(0.0089)	6.2e-10(1.9e+05)
	p-going	
	a	**b**
Old GX	0.069(0.0076)	1e-09(1.3e+05)
NKD	0.066(0.0064)	2e-09(9.6e+04)
NKS	0.075(0.0077)	1e-09(1.5e+05)
L	0.094(0.014)	1.3e-10(3.9e+05)

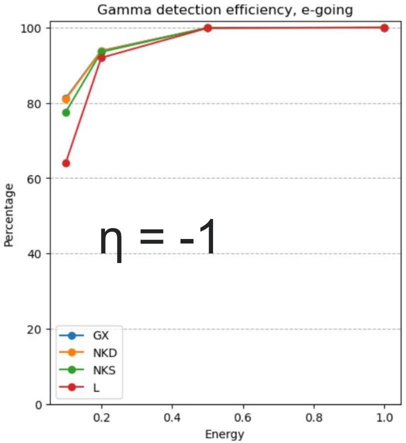
Low Energy Gamma - Efficiency

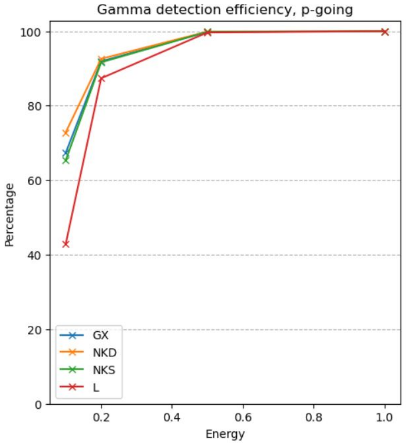
At least **3 cells** above 5 MeV threshold required per side



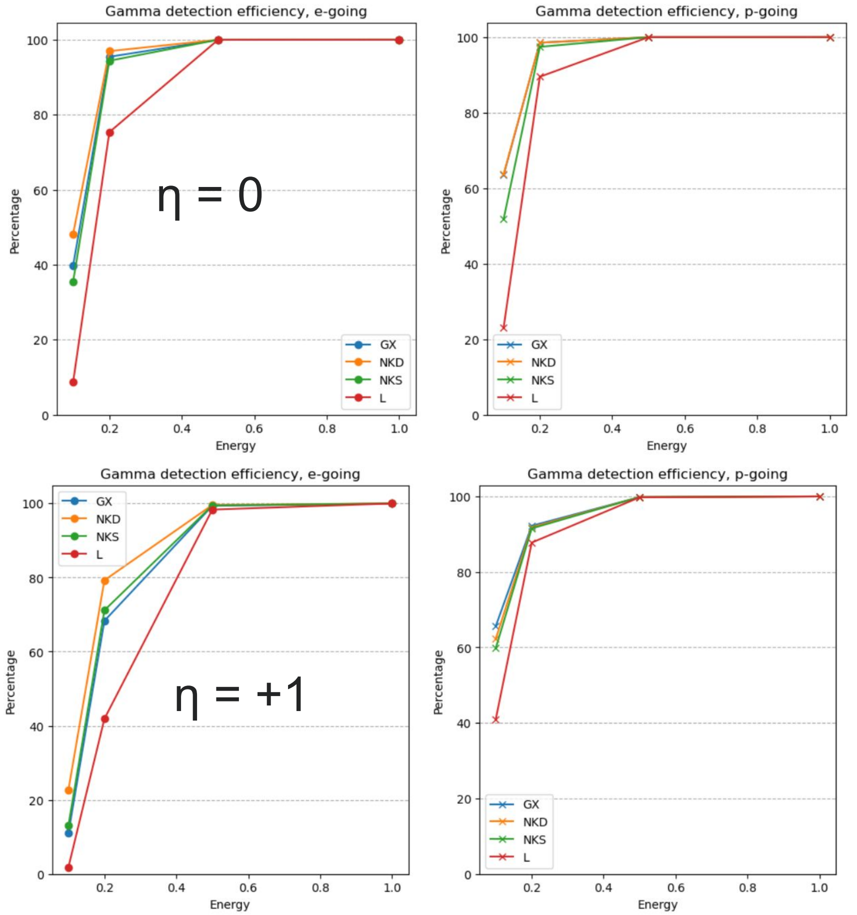


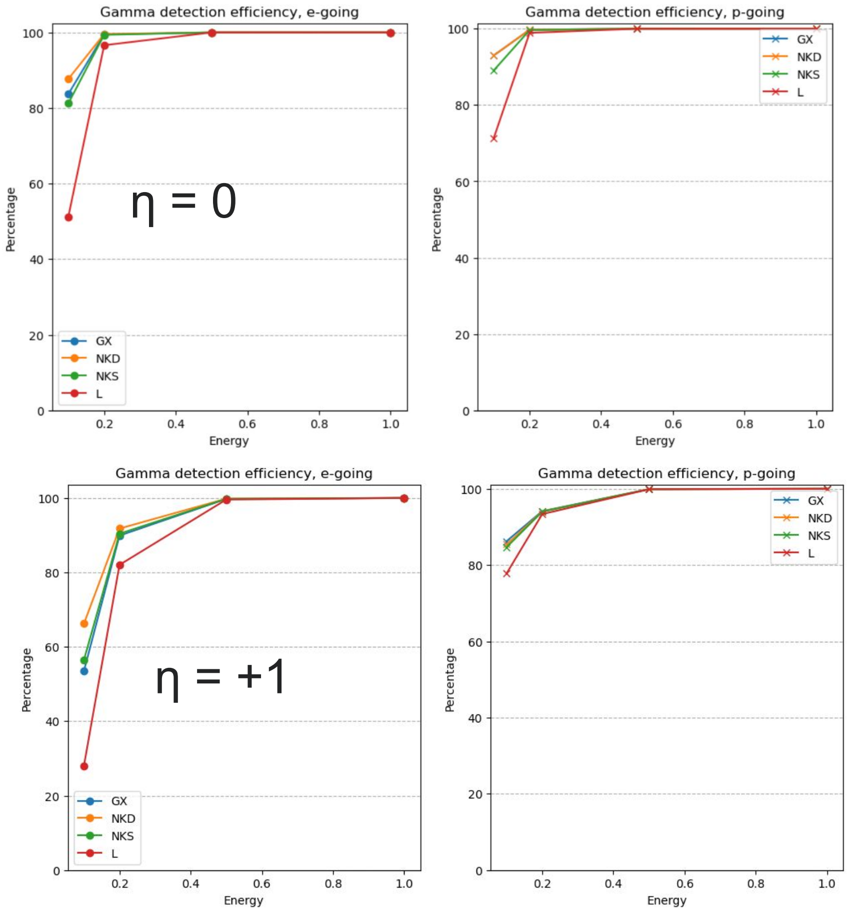
At least **2 cells** above 5 MeV threshold required per side





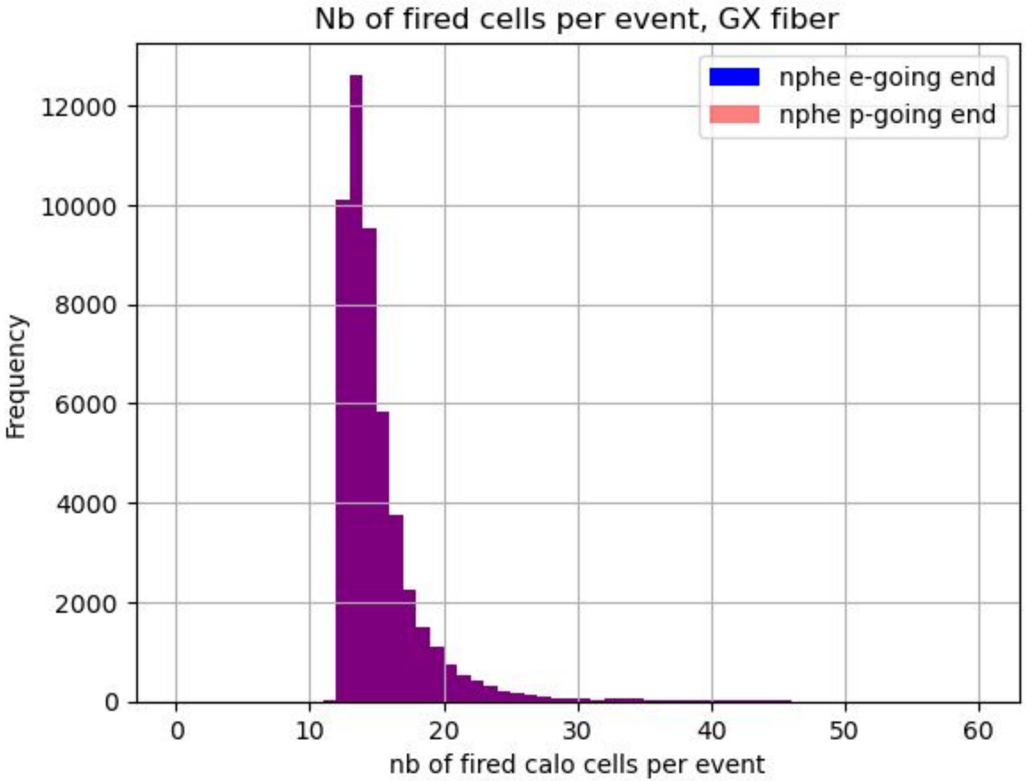
Low Energy Gamma - Efficiency





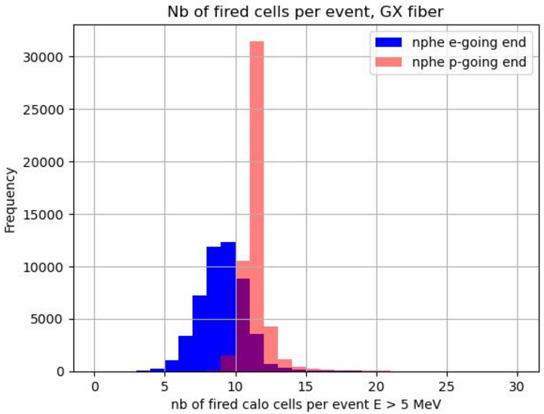
MIPs at η = 0, number of cells fired, true energy

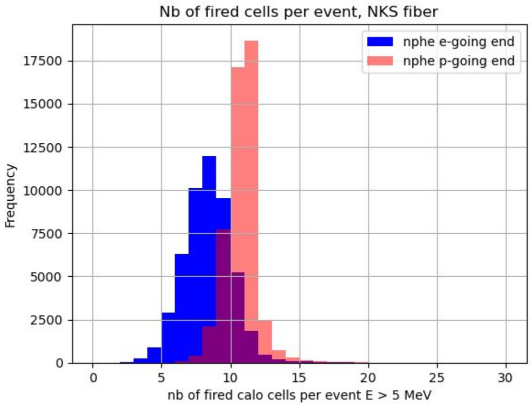
Muons at 5 GeV

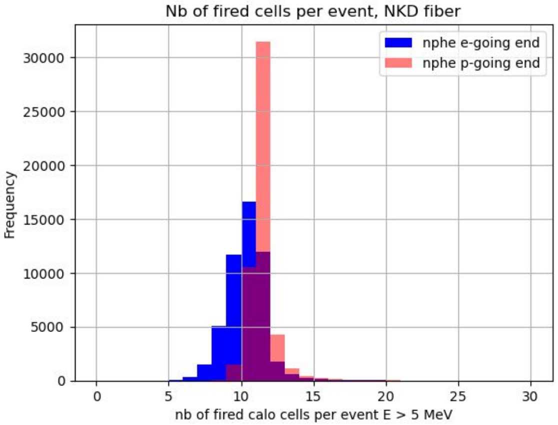


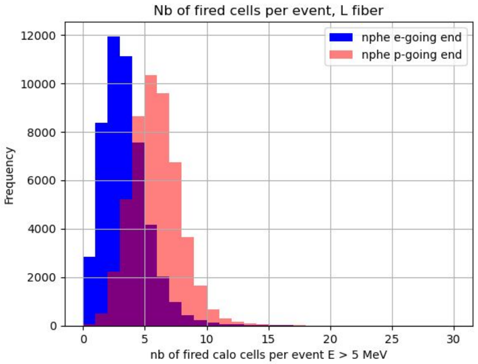
MIPs at η = 0, number of cells fired, attenuated energy

Muons at 5 GeV, 0.5 MeV threshold cut

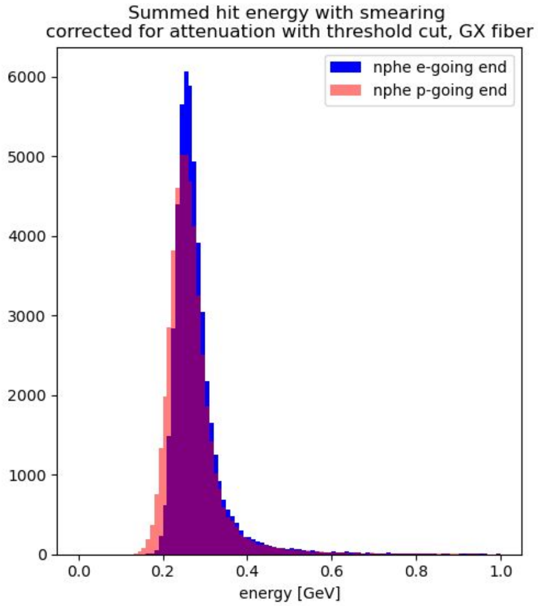




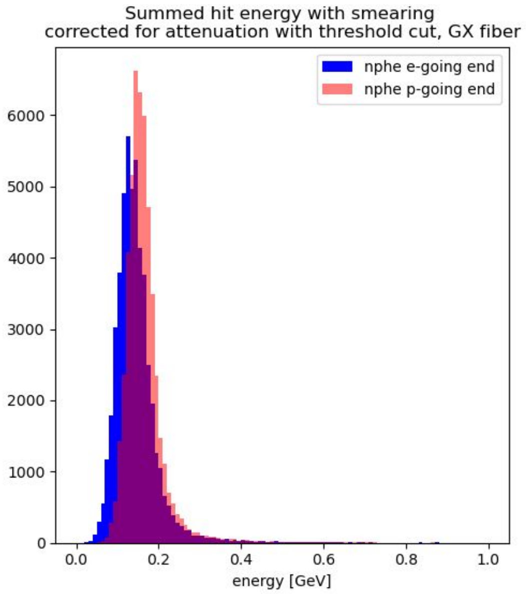




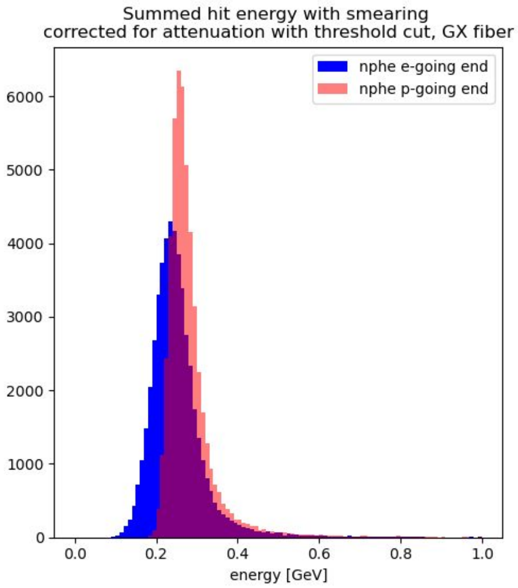
Energy deposit from muons



eta = -1

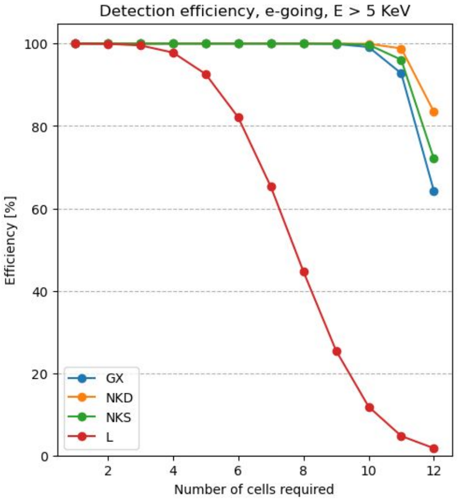


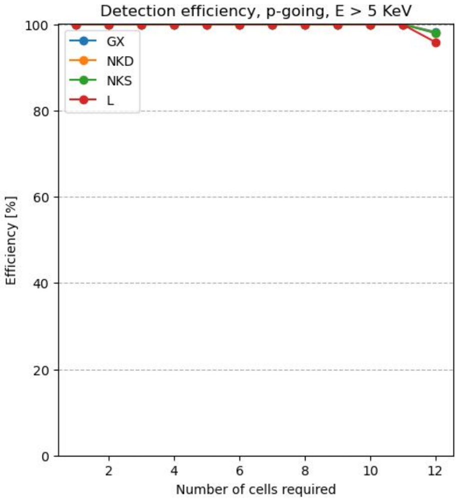
eta = 0



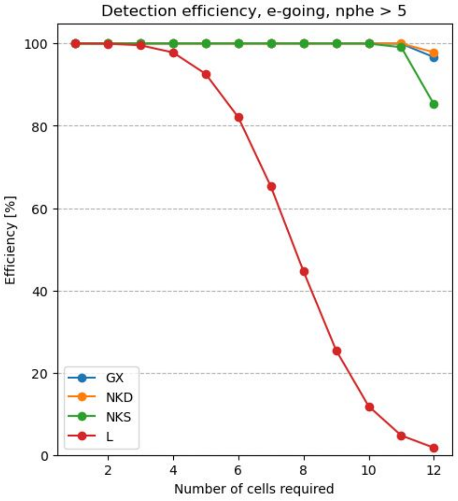
eta = +1

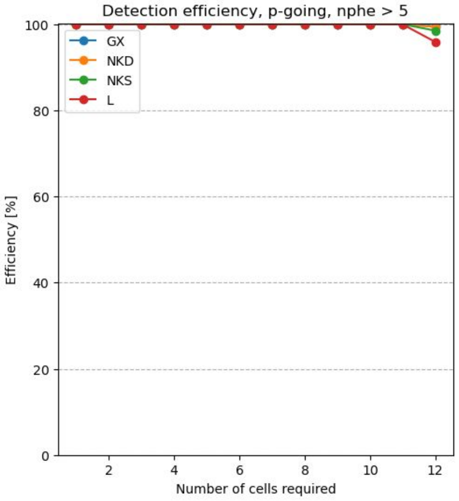
MIPs at η = +1 detection efficiency





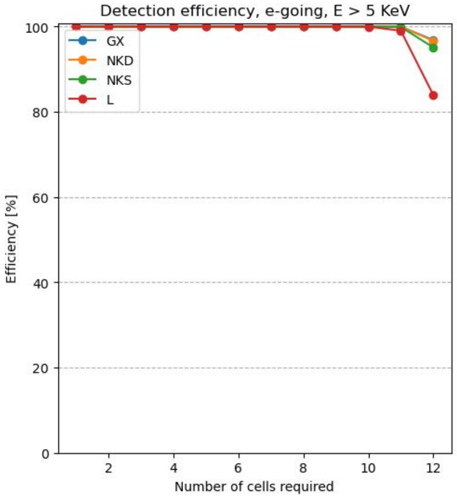
GX e cut: 0.005 GeV = nphe cut: 9.5
NKD e cut: 0.005 GeV = nphe cut: 9.4
NKS e cut: 0.005 GeV = nphe cut: 6.4
L e cut: 0.005 GeV = nphe cut: 5.1

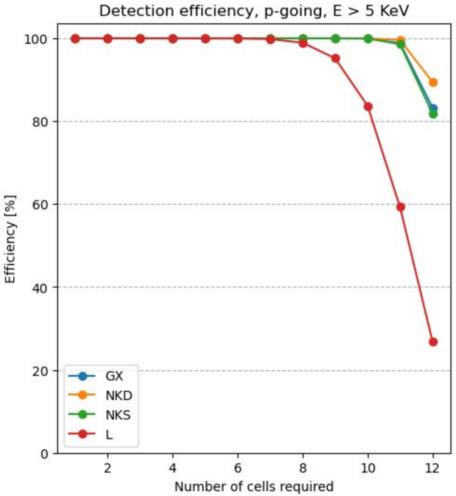


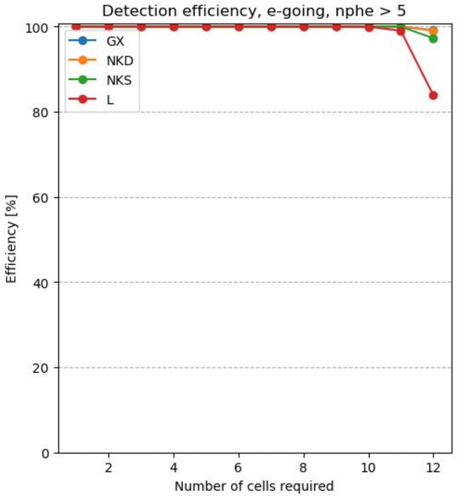


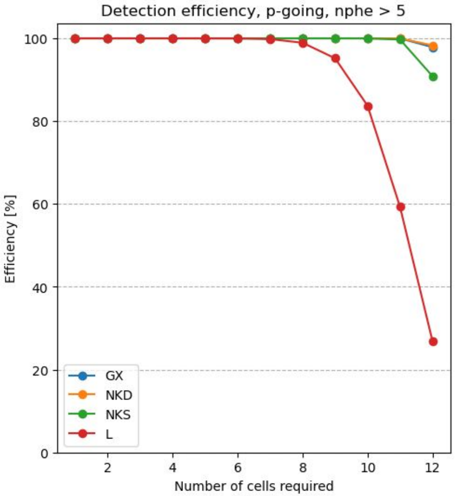
GX nphe cut: 5 = e cut: 0.0026 GeV
NKD nphe cut: 5 = e cut: 0.0026 GeV
NKS nphe cut: 5 = e cut: 0.0038 GeV
L nphe cut: 5 = e cut: 0.0048 GeV

MIPs at η = -1 detection efficiency





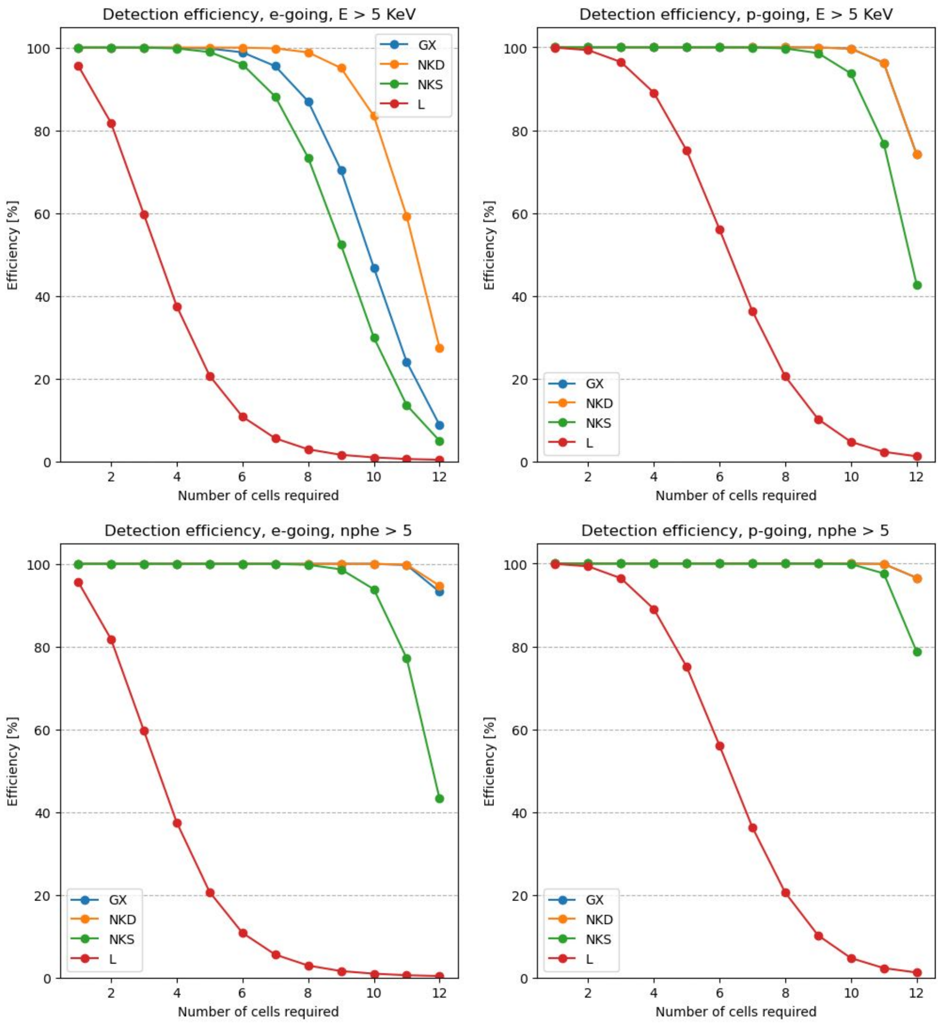




GX e cut: 0.005 GeV = nphe cut: 9.5
NKD e cut: 0.005 GeV = nphe cut: 9.4
NKS e cut: 0.005 GeV = nphe cut: 6.4
L e cut: 0.005 GeV = nphe cut: 5.1

GX nphe cut: 5 = e cut: 0.0026 GeV
NKD nphe cut: 5 = e cut: 0.0026 GeV
NKS nphe cut: 5 = e cut: 0.0038 GeV
L nphe cut: 5 = e cut: 0.0048 GeV

MIPs at η = 0 detection efficiency



GX e cut: 0.005 GeV = nphe cut: 9.5
NKD e cut: 0.005 GeV = nphe cut: 9.4
NKS e cut: 0.005 GeV = nphe cut: 6.4
L e cut: 0.005 GeV = nphe cut: 5.1

GX nphe cut: 5 = e cut: 0.0026 GeV
NKD nphe cut: 5 = e cut: 0.0026 GeV
NKS nphe cut: 5 = e cut: 0.0038 GeV
L nphe cut: 5 = e cut: 0.0048 GeV

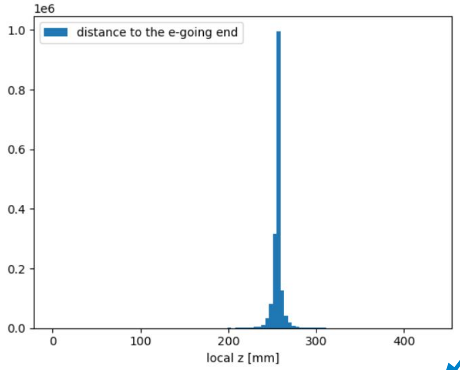
OPEN/DISCUSSION QUESTIONS

- What light yield is necessary to see the MIP?

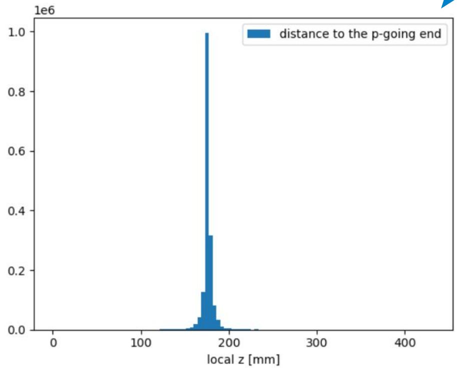
- Can we use spools, or do we need canes?

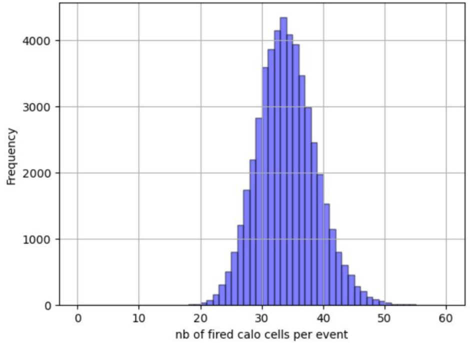
BACKUP

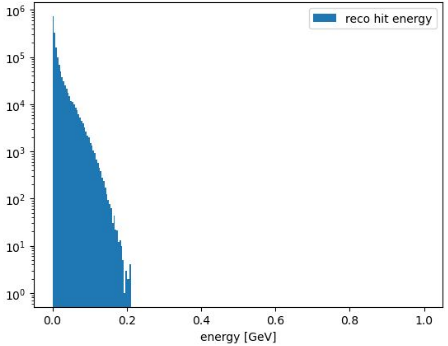
Proof-of-principle: 500 MeV electrons

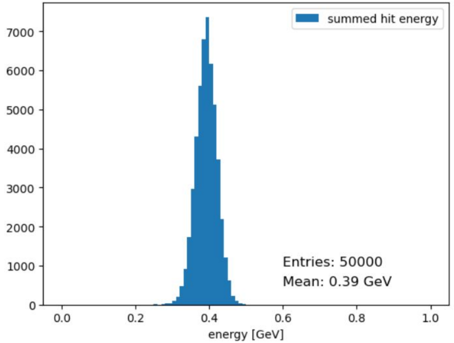


η = 0, different distance to p- and e-going end of sector



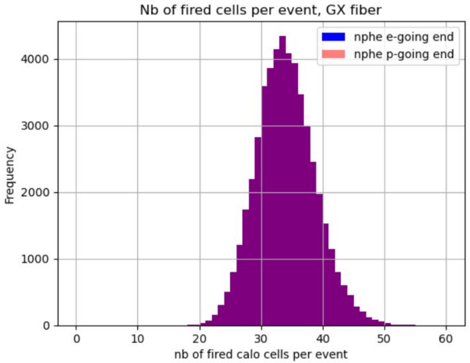


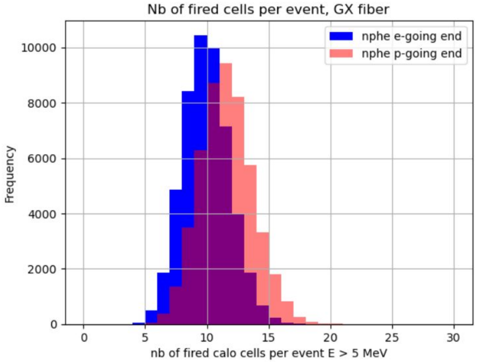


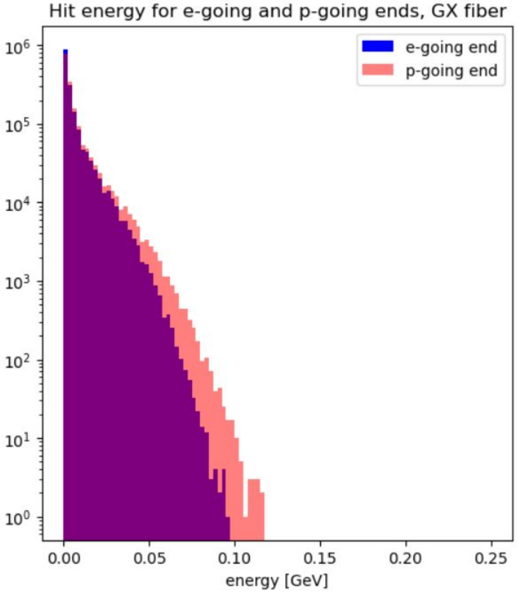


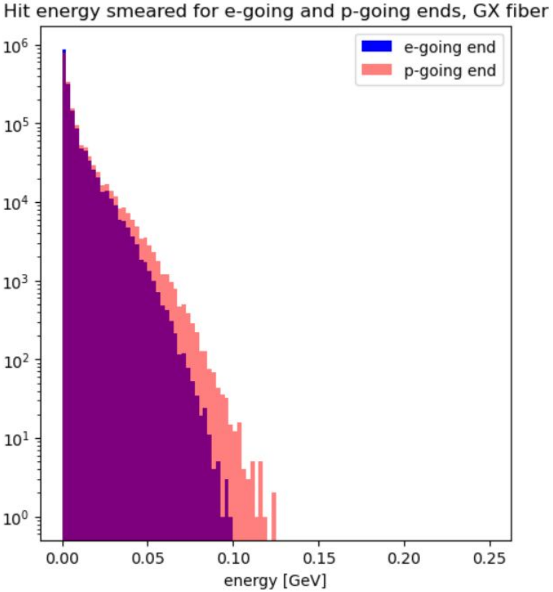
Proof-of-principle: 500 MeV electrons

Kuraray Old Double Clad (GlueX) fiber

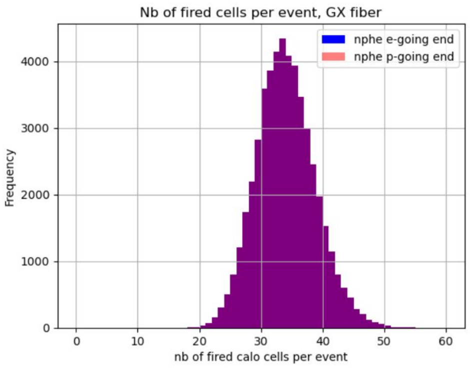


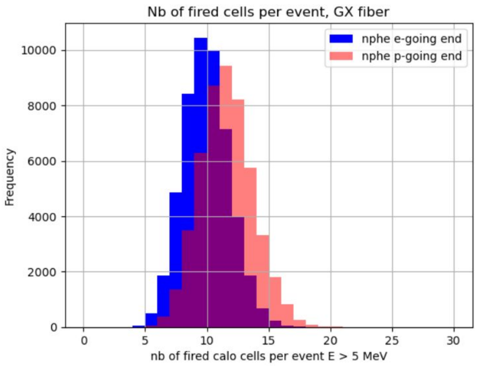




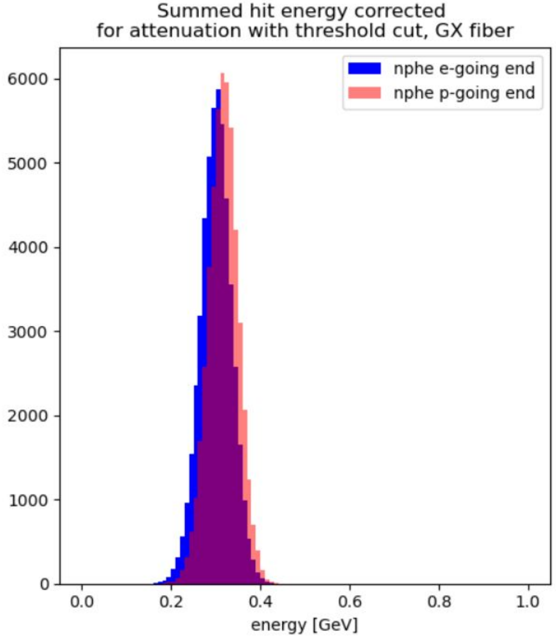


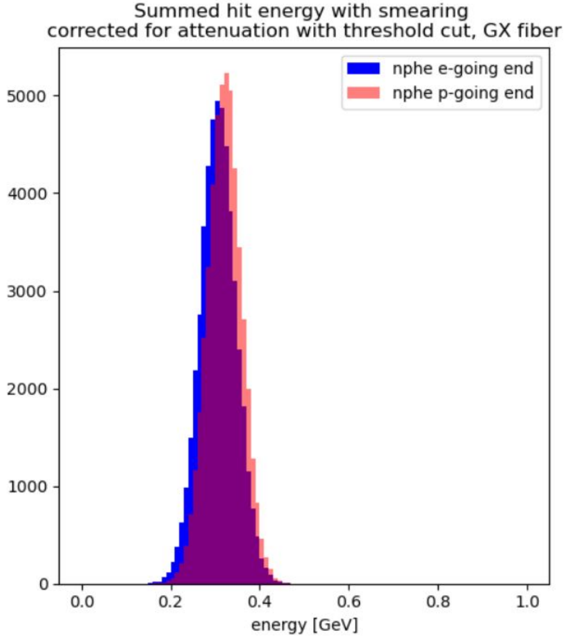
Proof-of-principle: 500 MeV electrons



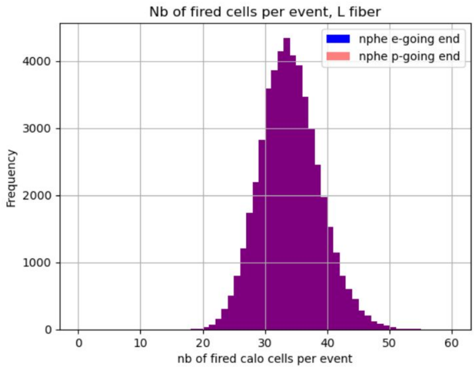


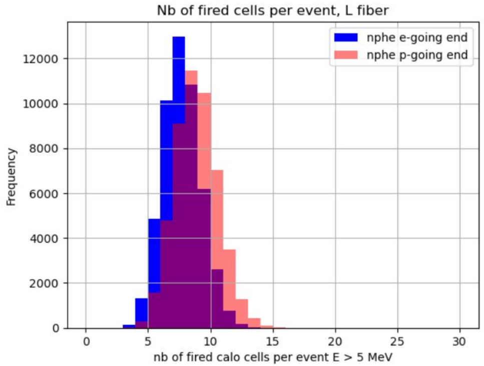
Kuraray Old Double Clad (GlueX) fiber



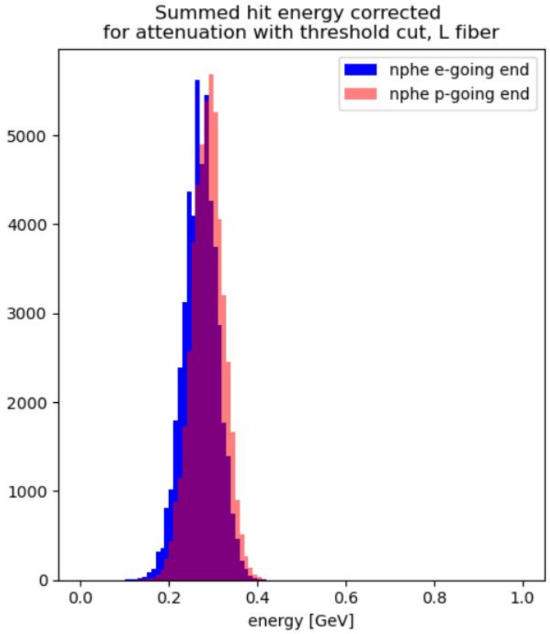


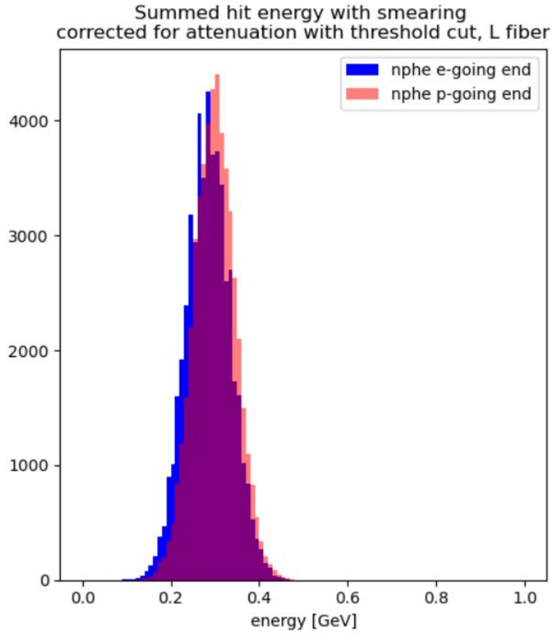
Proof-of-principle: 500 MeV electrons



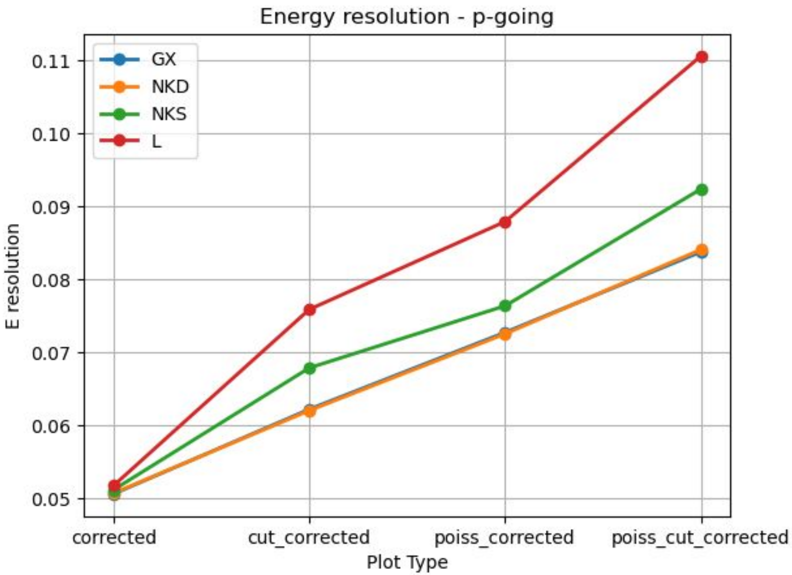


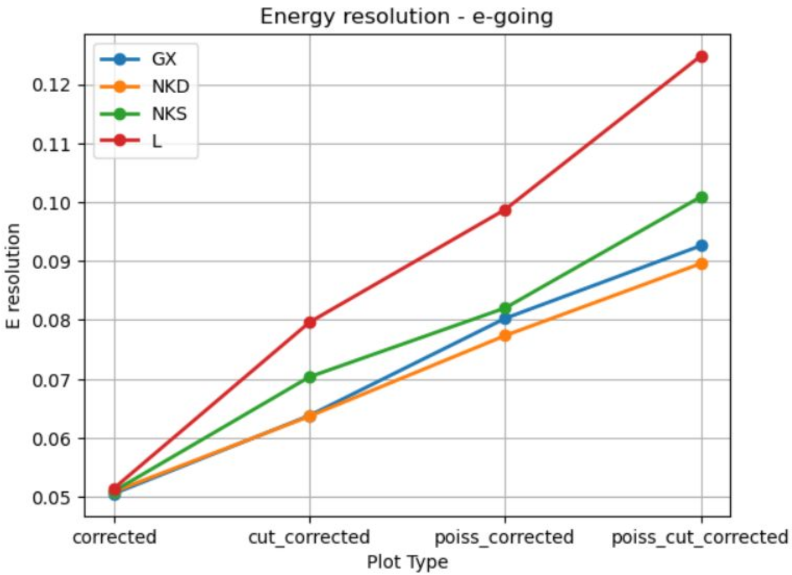
Luxium fiber



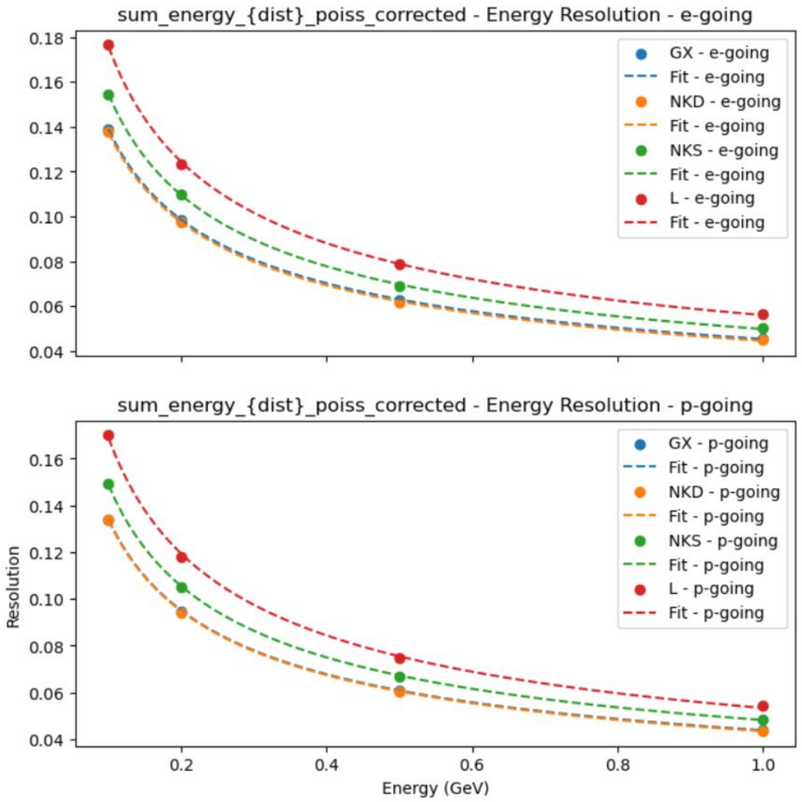


500 MeV electrons - energy resolution





Low Energy Gammas - Energy Resolution



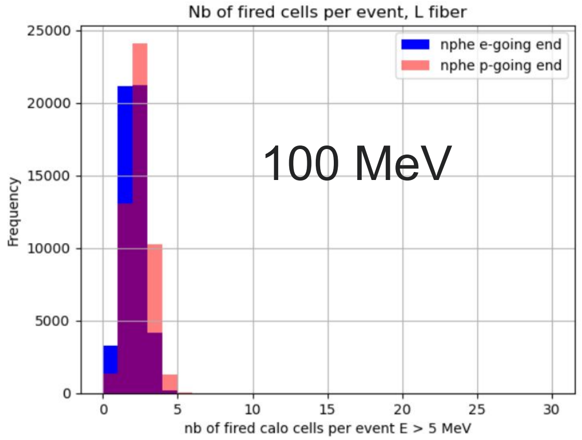
Fitted parameters for GX - e-going: a = 0.044, b = 0.012
Fitted parameters for GX - p-going: a = 0.042, b = 0.012

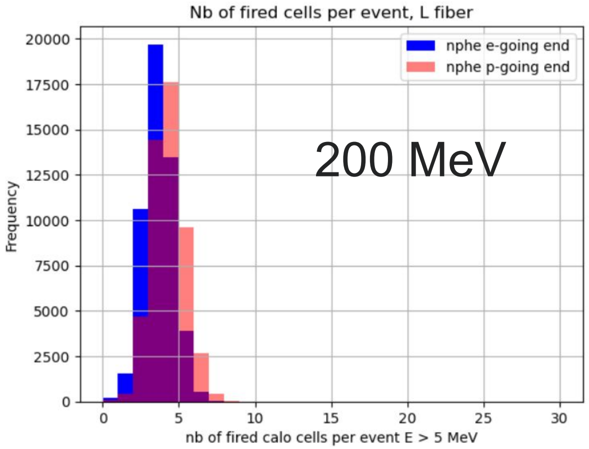
Fitted parameters for NKD - e-going: a = 0.043, b = 0.01
Fitted parameters for NKD - p-going: a = 0.042, b = 0.011

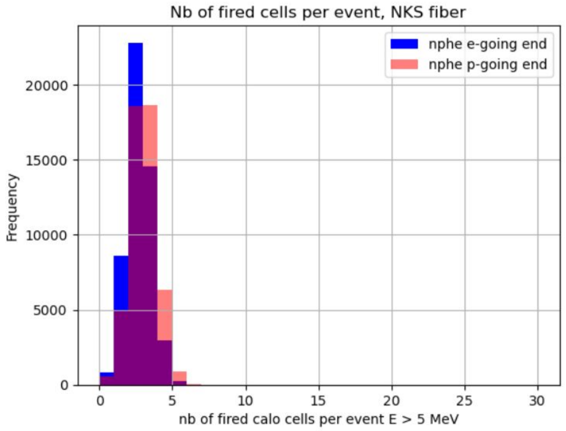
Fitted parameters for NKS - e-going: a = 0.049, b = 0.0095
Fitted parameters for NKS - p-going: a = 0.047, b = 0.011

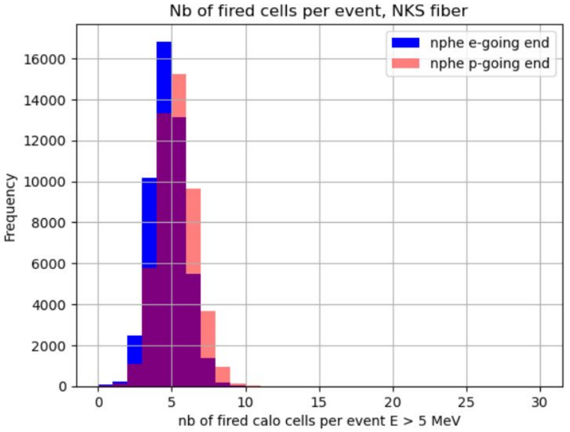
Fitted parameters for L - e-going: a = 0.056, b = 0.0067
Fitted parameters for L - p-going: a = 0.053, b = 1.4e-08

Low Energy Gammas - 100 MeV and 200 MeV









Low Energy Gammas - 100 MeV and 200 MeV