The impact of JUNO scintillator parameters in SNiPER

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JUNO meeting EU + AM
26/10/2022

GOAL OF THE STUDIES

Study the **impact** of the **LS parameters** and LS **physical processes** on the simulations for **NMO**

Understand how **SNiPER works**

- **Which** LS **parameters** are implemented and where
- **How** to **modify** the default parameters

Study the **impact** of LS parameters and processes on the **energy resolution**

- Study the **impact** of the **quenching** and the **Cherenkov** effect
- Insert **SHELDON** and SHELDON-REWIND **parameters**

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THE LS PARAMETERS IN SNiPER

Property	Default value	Implementation file ["/data/Simulation/DetSim/Material/LS/" +]	Easily-modifiable
Light-yield	9507/MeV	ConstantProperty	Yes
Birks' constant 1 (k_B)	$6.5 \cdot 10^{-3}$g/cm2/MeV	ConstantProperty	Yes
Birks' constant 2 (k_C)	$1.5 \cdot 10^{-6}$ (g/cm2/MeV)^2	ConstantProperty	Yes
Cherenkov yield factor	1 (see later)	-	Yes
Refractive index	f(λ)	RINDEX	No
Absorption length	f(λ)	ABSLENGTH_v1	No
Emission spectrum	f(λ)	FASTCOMPONENT / SLOWCOMPONENT	No
Re-emission	f(λ)	REEMISSIONPROB	No
Rayleigh length	f(λ)	RAYLEIGH	No
Fluorescence times	particle-dependent	AlphaCONSTANT / NeutronCONSTANT / GammaCONSTANT	No

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Birks' constant 2 (k_C)	$1.5 \cdot 10^{-6}$ (g/cm2/MeV)^2		
Cherenkov yield factor	1 (see later)		
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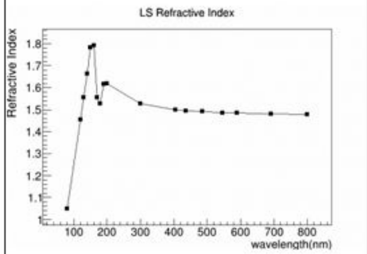
THE SEARCH FOR THE LS PARAMETERS

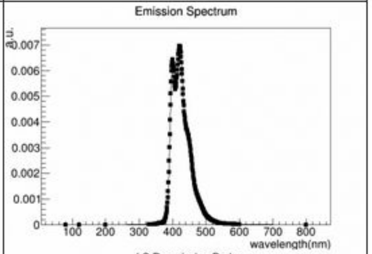
- At the beginning of the search I found the **JUNO-wiki** page: https://juno.ihep.ac.cn/mediawiki/index.php/Analysis:Basic_Distributions_of_JUNO

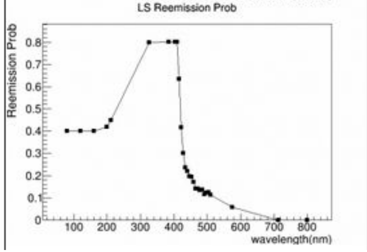
  which was supposed to contain a **documentation** of all the **LS plots** (and a few more) which are inserted **in SNiPER**;

- It had **not been updated** for a **few year** → a **deep search in SNiPER** was needed;
- Then I **updated** the **JUNO-wiki page** (with the permission of Tao Lin and Ziyan Deng).

THE JUNO-WIKI PAGE

<table>
<tr>
<td>LS refractive index</td>
<td>
Light yield (SCINTILLATIONYIELD)
9507/MeV
file: $data/Simulation/DetSim/Material/LS/ConstantProperty
Note the scale factor of 0.8251 in: $data/Simulation/DetSim/Material/LS/scale due to the new PMT model
Refractive index (RINDEX)
file: $data/Simulation/DetSim/Material/LS/RINDEX
</td>
<td>


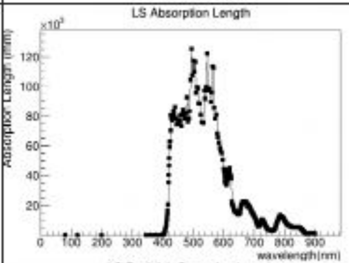
</td>
</tr>
<tr>
<td>b) LS Emission spectrum & reemission probability</td>
<td>
Emission spectrum (FASTCOMPONENT)
file: $data/Simulation/DetSim/Material/LS/FASTCOMPONENT
Re-emission prob (REEMISSIONPROB)
file: $data/Simulation/DetSim/Material/LS/REEMISSIONPROB
</td>
<td>


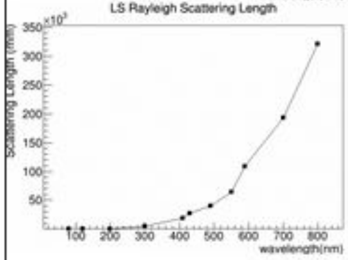


</td>
</tr>
</table>

THE JUNO-WIKI PAGE

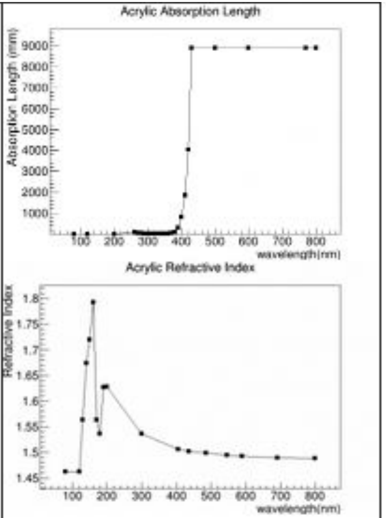
<table>
<tr>
<td>LS absorption length and refractive index</td>
<td>
Absorption length (ABSLENGTH)
file: $data/Simulation/DetSim/Material/LS/ABSLENGTH
Note the scale factor of 77/26 in: $data/Simulation/DetSim/Material/LS/scale

Rayleigh length (RAYLEIGH)
file: $data/Simulation/DetSim/Material/LS/RAYLEIGH
Note the scale factor of 27/42 in: $data/Simulation/DetSim/Material/LS/scale
</td>
<td>




</td>
</tr>
</table>

THE JUNO-WIKI PAGE

Acrylic absorption length and Rayleigh length	**Absorption length** (`ABSLENGTH`) file: `$data/Simulation/DetSim/Material/Acrylic/ABSLENGTH` **Refractive index** (`RINDEX`) file: `$data/Simulation/DetSim/Material/Acrylic/RINDEX`	
		R12860 20-inches phototubes QE

THE JUNO-WIKI PAGE

PMT QE

Pyrex refractive index

R12860 Quantum Effieciency (20-inches phototubes QE)

file: `$/data/Simulation/DetSim/PMTProperty/R12860/QE_shape`

R12860 Collection Efficiency (20-inches phototubes CE)

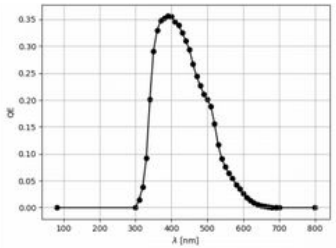
file: `$/data/Simulation/DetSim/PMTProperty/R12860/CE`

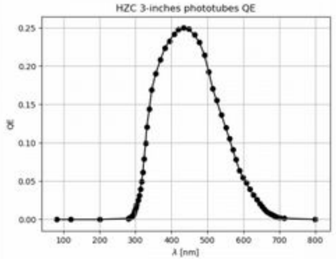
HZC Quantum Efficiency (3-inches phototubes QE)

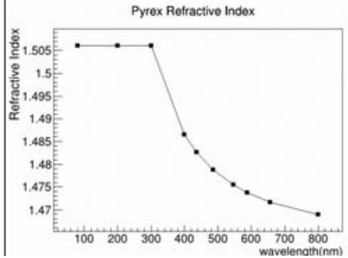
file: `$/data/Simulation/DetSim/PMTProperty/HZC_3inch/QE_shape`

Refractive index (Pyrex RINDEX)

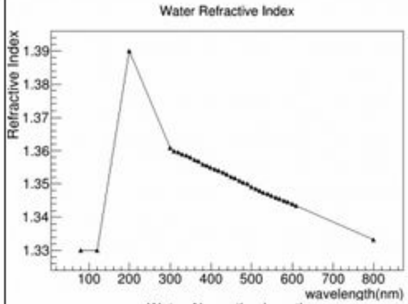
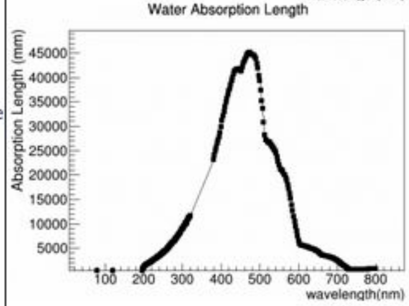
file: `$data/Simulation/DetSim/Material/Pyrex/RINDEX`





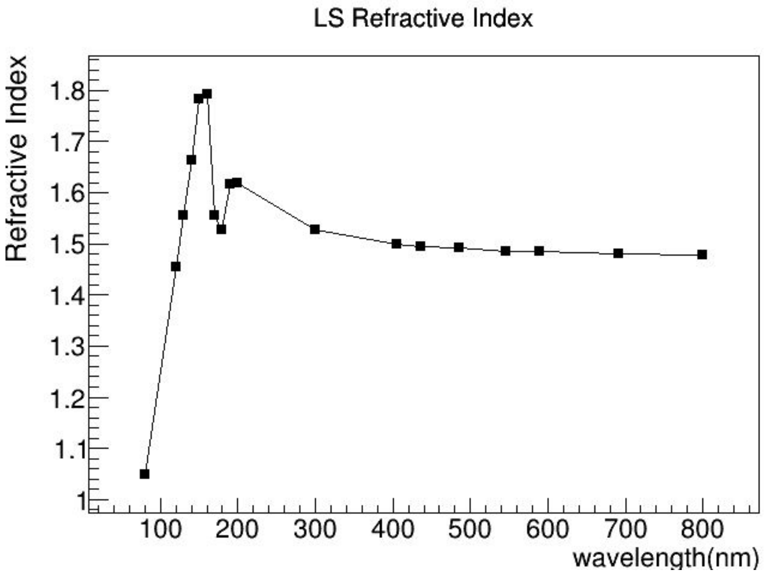


THE JUNO-WIKI PAGE

Water refractive index	**Refractive index (RINDEX)** file: `$data/Simulation/DetSim/Material/Water/RINDEX`	
Water absorption length	**Absorption length (ABSLENGTH)** file: `$data/Simulation/DetSim/Material/Water/ABSLENGTH` Note the scale factor of 1.5084 in: `$data/Simulation/DetSim/Material/Water/scale`	

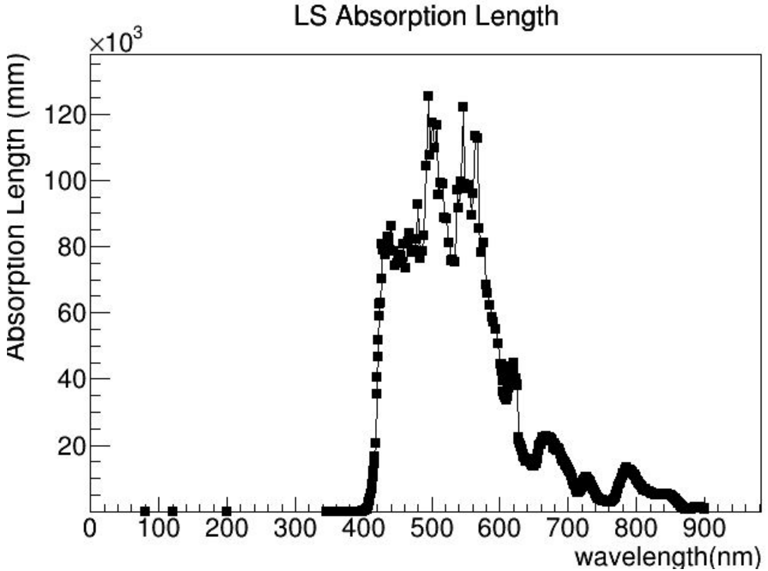
A PLOT OF THE LS PARAMETERS

Plots from the JUNOwiki page: https://juno.ihep.ac.cn/mediawiki/index.php/Analysis:Basic_Distributions_of_JUNO



From: >400nm experimental results;
200-400nm dispersion formula;
120-200nm Kamland inherited;
80-120nm linear extrapolation

When: 2021



From: Daya Bay inherited, rescaled due to different transparesce

When: <2015

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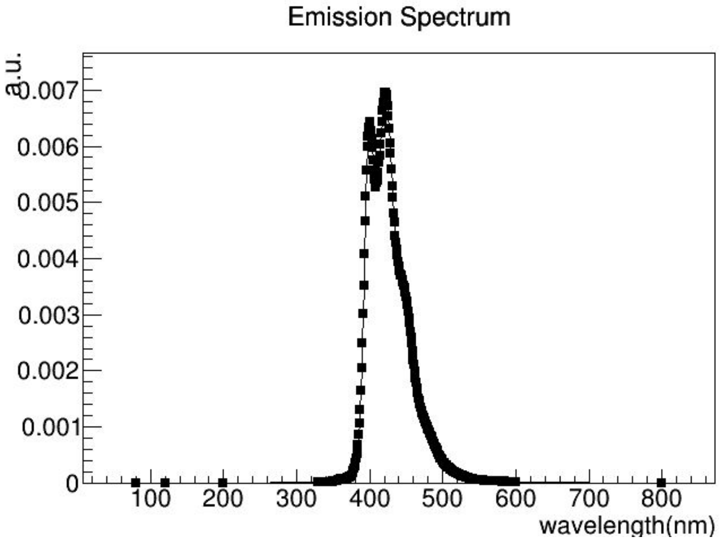
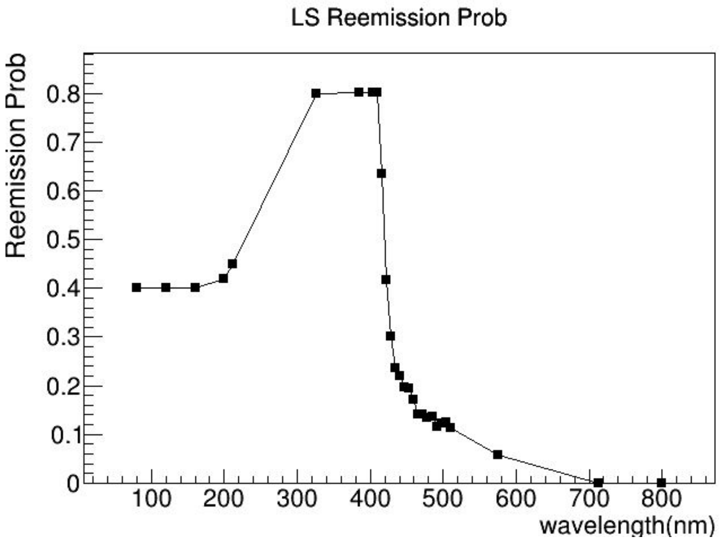


From: Daya Bay inherited

When: <2015



From: Daya Bay inherited

When: <2015

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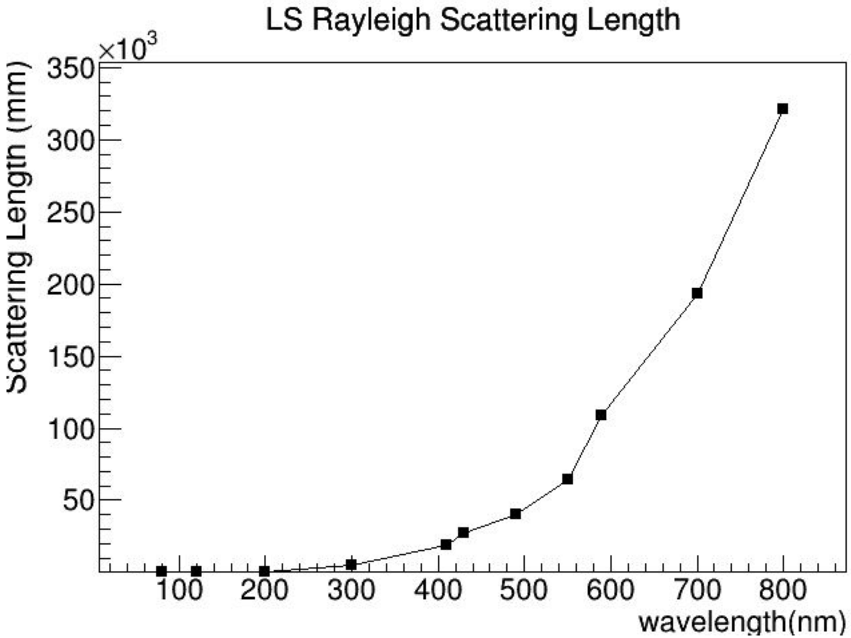

From: Daya Bay inherited

When: <2015

Fluorescence times

PARTICLE	τ_1 [ns] / ratio	τ_2 [ns] / ratio	τ_3 [ns] / ratio	τ_4 [ns] / ratio
e^-, e^+, γ	4.6 / 70.7%	15.1 / 20.5%	76.1 / 6.0%	397 / 2.8%
p, n	4.5 / 61.4%	15.7 / 23.2%	76.2 / 9.0%	367 / 6.4%
α	4.345 / 49.82%	17.64 / 27.39%	89.045 / 14.67%	544.48 / 8.12%

From: e^- and p Munich
α unknown

When: e^- and p 2021
α recent

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- Insert **SHELDON** and SHELDON-REWIND **parameters**

HOW TO CHANGE THE DEFAULT PARAMETERS

- To change the **light-yield**, **Birks' constants**, **Cherenkov yield factor** an **instruction** while launching a simulation is enough;

```
python tut_detsim.py --cerenkov-yield-factor 0.517 --replace-param
Material.LS.ConstantProperty.ScintillationYield:9846/MeV,Material.LS.Consta
ntProperty.BirksConstant1:12.05e3*g/cm2/MeV,Material.LS.ConstantProperty.
BirksConstant2:0 gun
```

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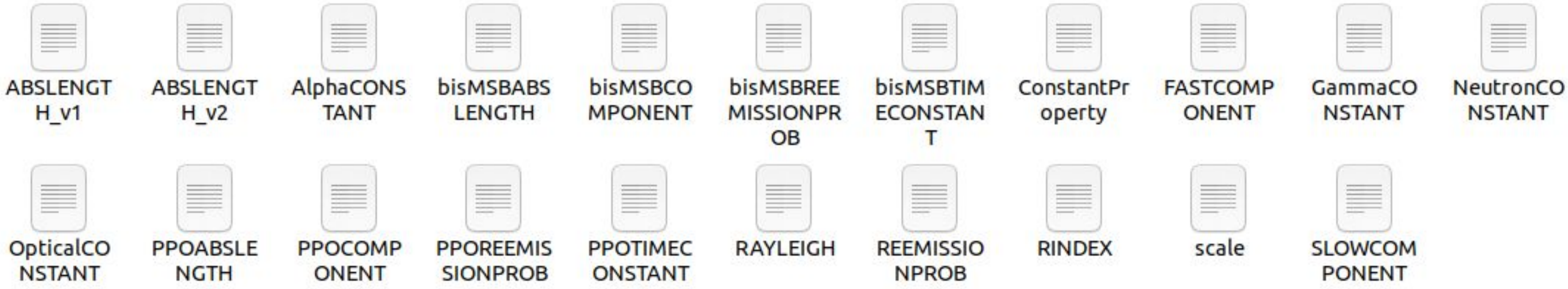
- To change the **light-yield**, **Birks' constants**, **Cherenkov yield factor** an **instruction** while launching a simulation is enough;
- For all the **other parameters** it is necessary to go in the SNiPER's LS directory and **modify the correct file**



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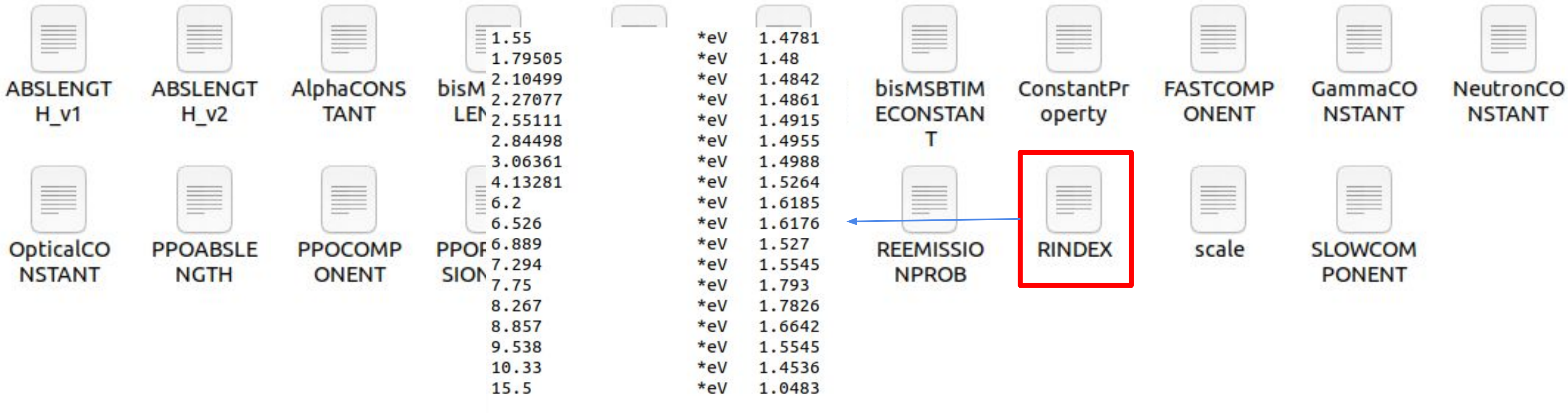

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THE IMPACT OF THE QUENCHING AND CHERENKOV

We expect the **quenching** and the **Cherenkov effect** to introduce **non-linearity** in energy reconstruction and **worsen** the **energy resolution**;

In **SNiPER** it is possible to easily **turn on/off** these effects;

Energy reconstruction and **resolution studies** were executed **turning on/off** these processes:

Version used: J22.1.0-rc0 (latest version available: J22.2.0-rc0);

Particles generated near the center of the detector (r=25cm);

The detector simulation and the event reconstruction were executed

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In **SN**

Ener

on/o

Versi

Particle	$E_{(kin)}$	Statistics
e-	0.5, 1,2,…,9 MeV	2k events/energy
e+	0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 4…9 MeV	2k events/energy
γ	0.5, 1,2,…,9 MeV	2k events/energy

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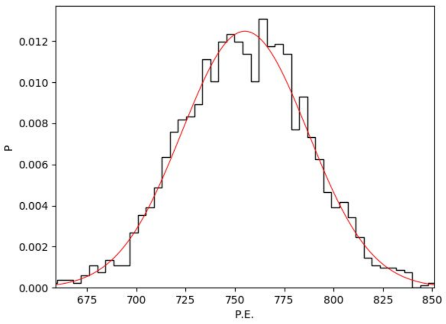
RESOLUTION STUDIES: THE METHOD

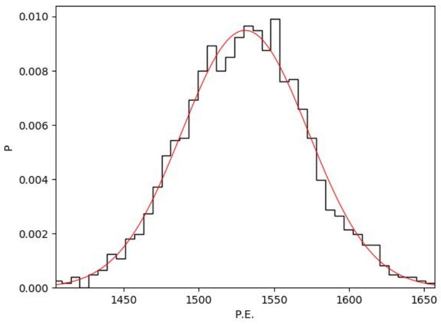
Cherenkov and **quenching switched off**

Particles: **electrons**

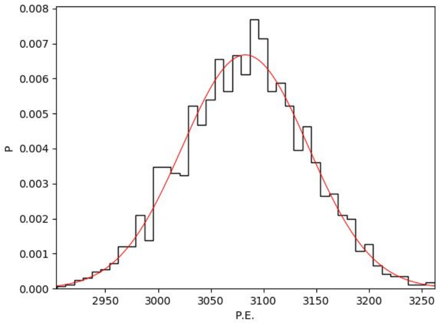
E(e-)=0.5MeV



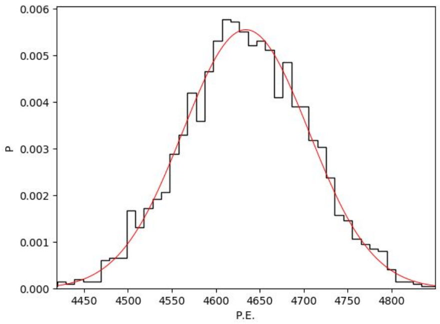
E(e-)=1MeV



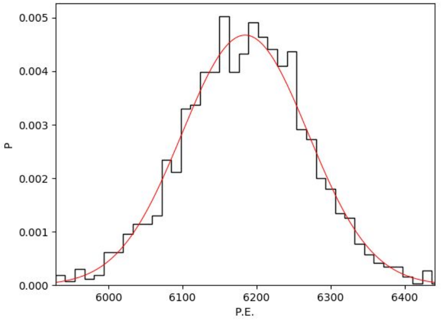
E(e-)=2MeV



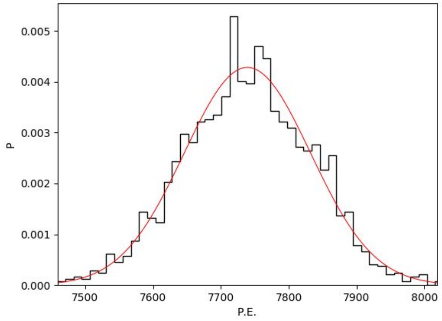
E(e-)=3MeV



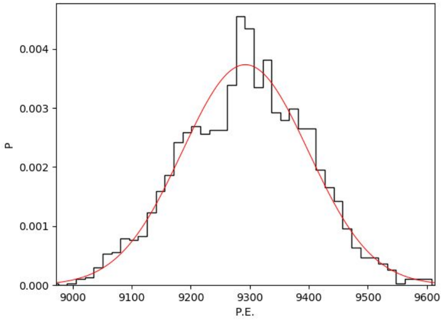
E(e-)=4MeV



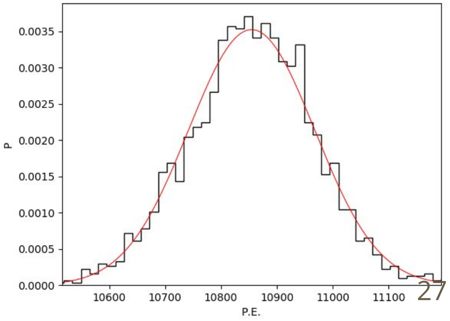
E(e-)=5MeV



E(e-)=6MeV



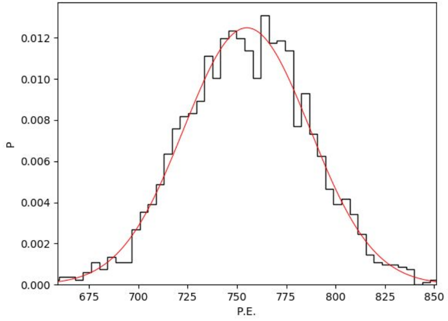
E(e-)=7MeV



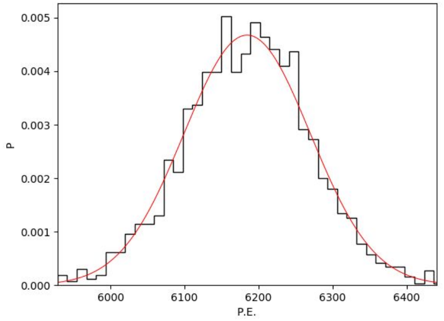
RESOLUTION STUDIES: THE METHOD

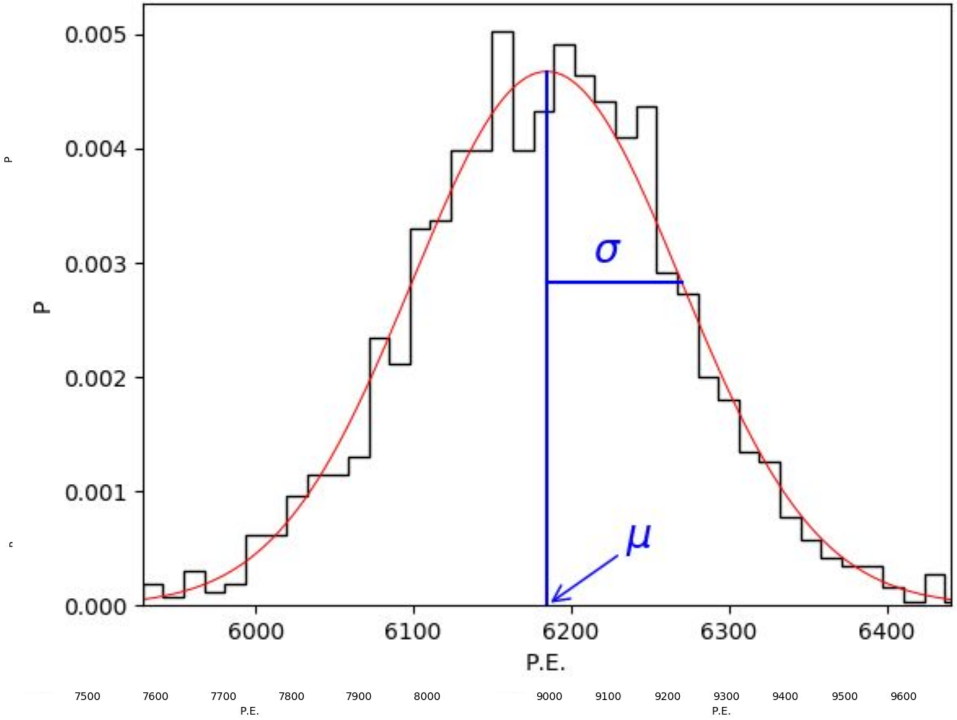
E(e-)=4MeV

E(e-)=0.5MeV



E(e-)=4MeV





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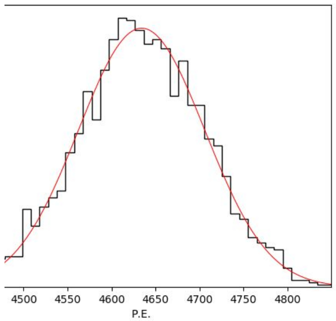

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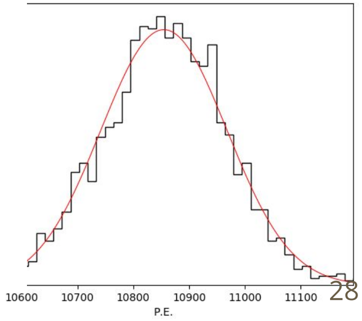
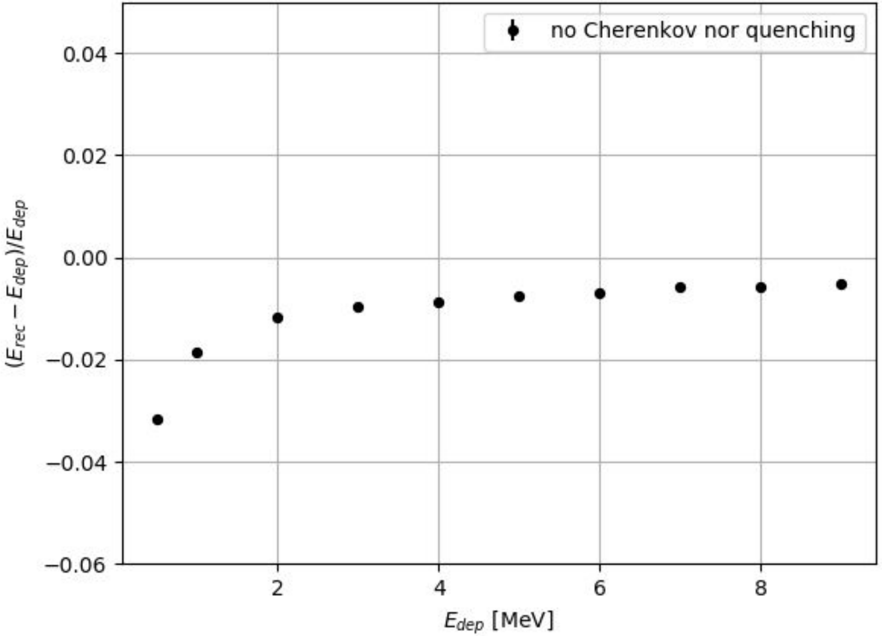


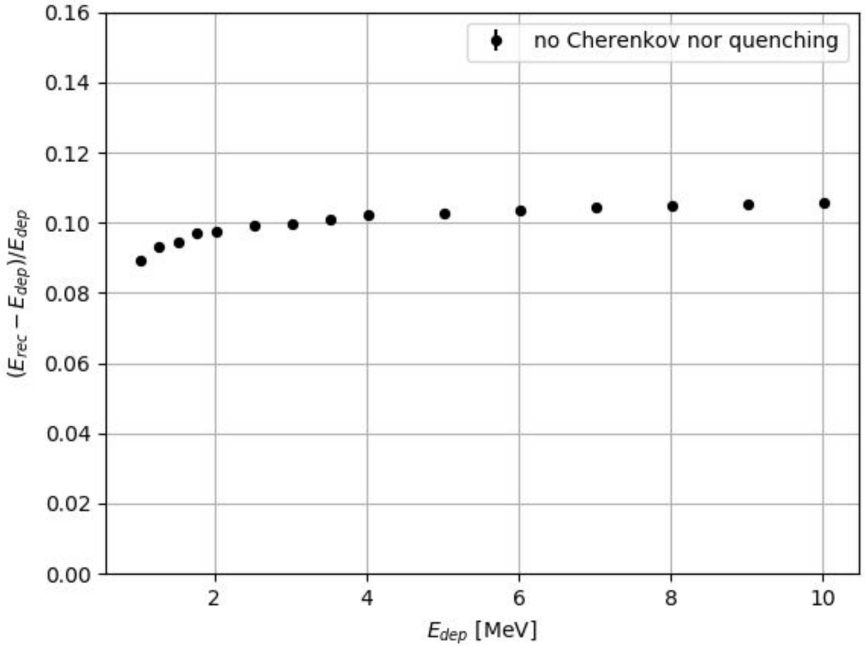
ENERGY RECONSTRUCTION RESULTS

The relative difference **$(E_{rec}-E_{dep})/E_{dep}$** gives information on the **non linearity** of the **reconstructed energy. Flat curves → Better linearity**

Electrons



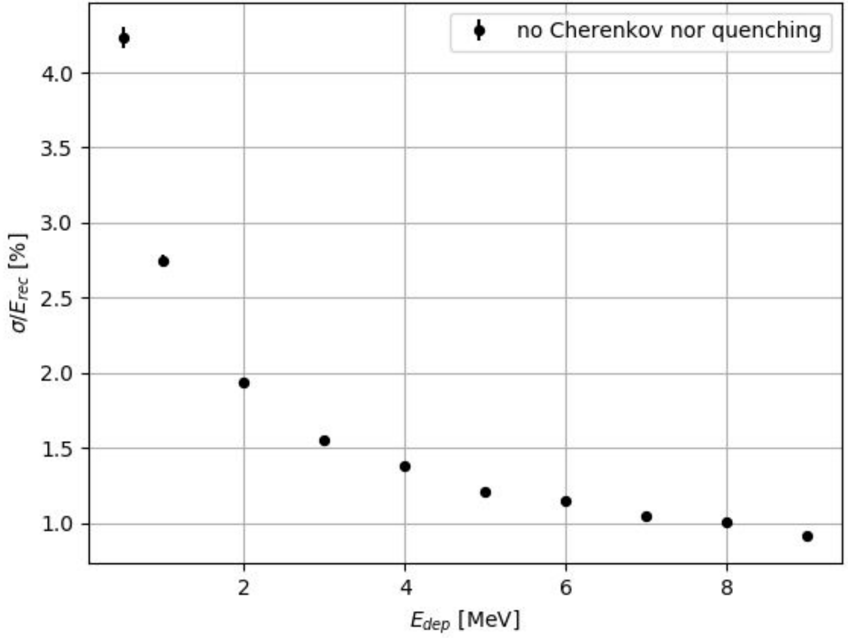
Positrons



ENERGY RESOLUTION RESULTS

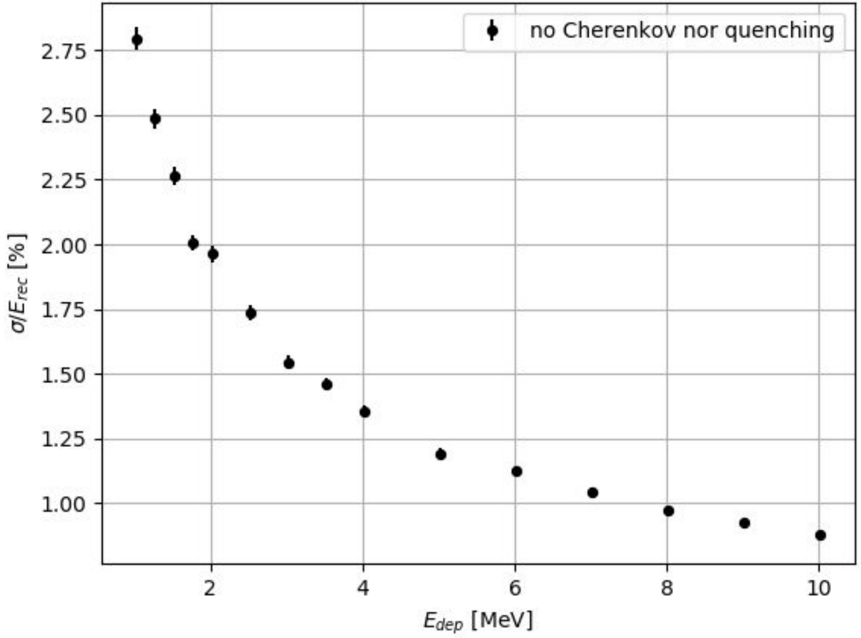
It was studied in terms of **σ/E_{rec}**

Electrons



Energy resolution @ 1MeV: (2.74 ± 0.04) %

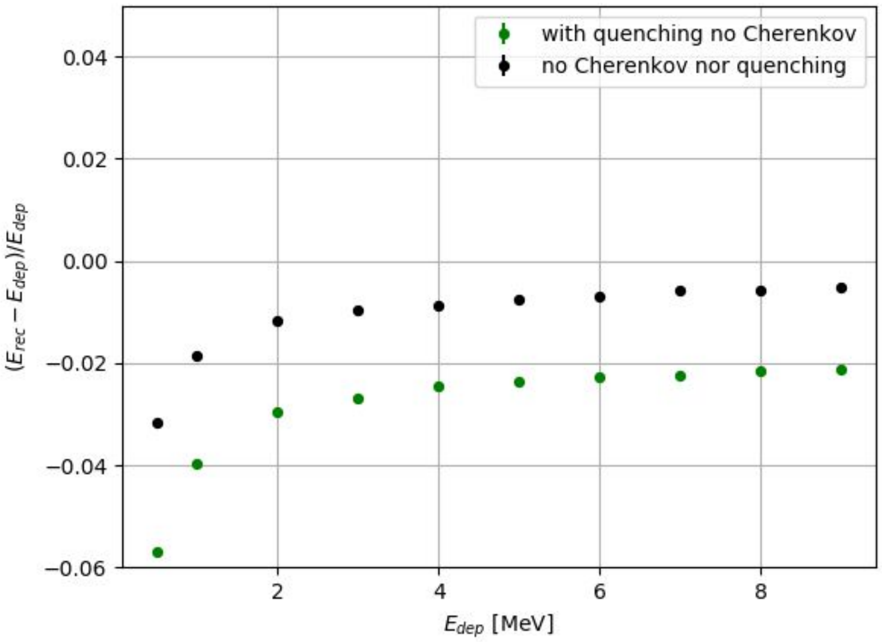
Positrons



Energy resolution @ 1.022MeV: (2.80 ± 0.04) %

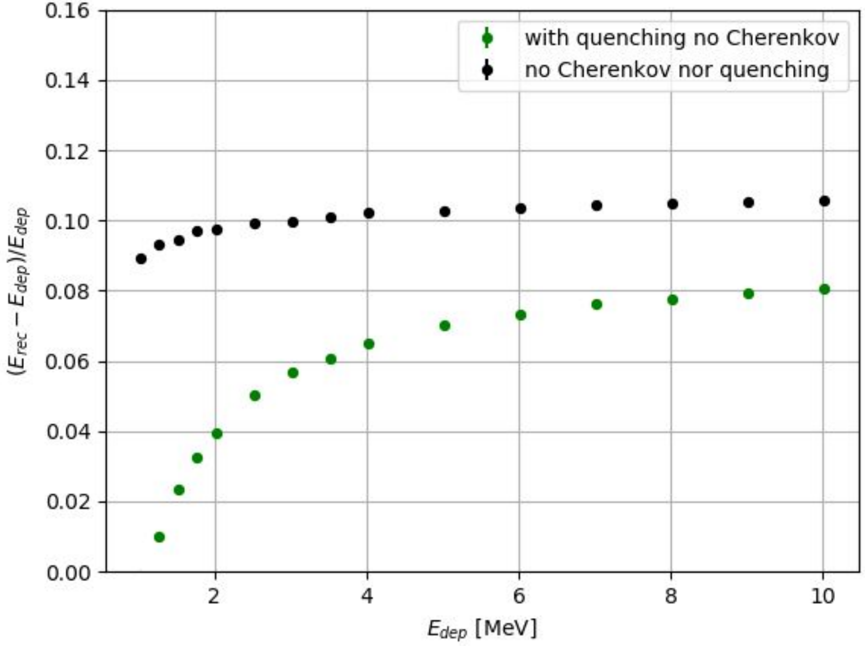
TURNING ON THE QUENCHING

Electrons



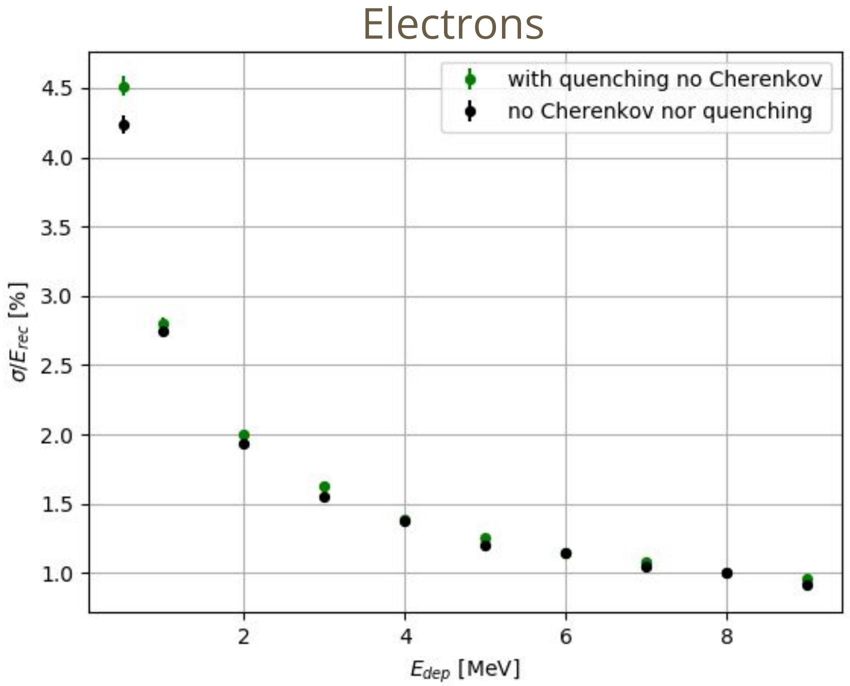
Not a great impact

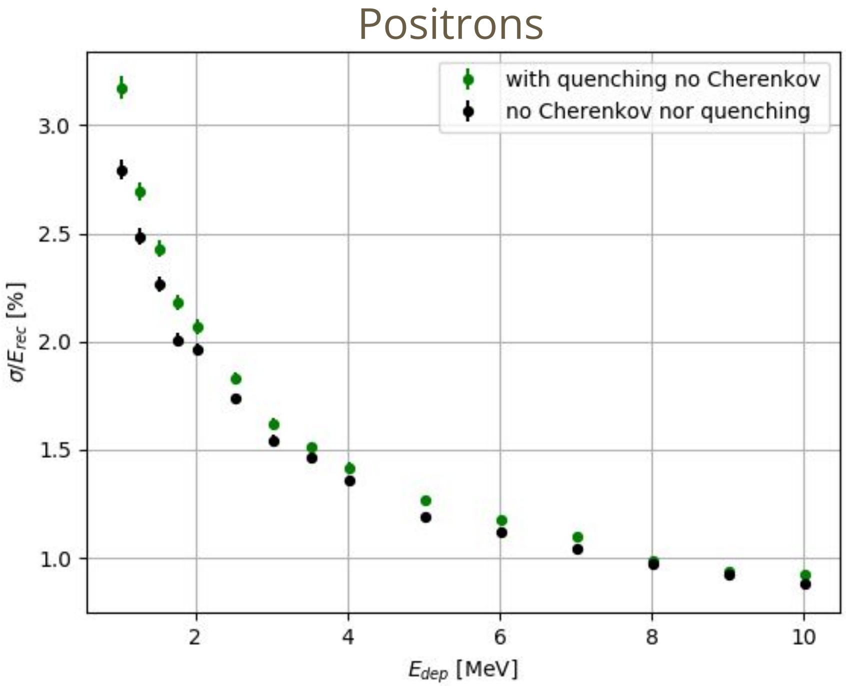
Positrons



Linearity worsens at low energy

TURNING ON THE QUENCHING





Energy resolution @ 1MeV: (2.74 ± 0.04) %

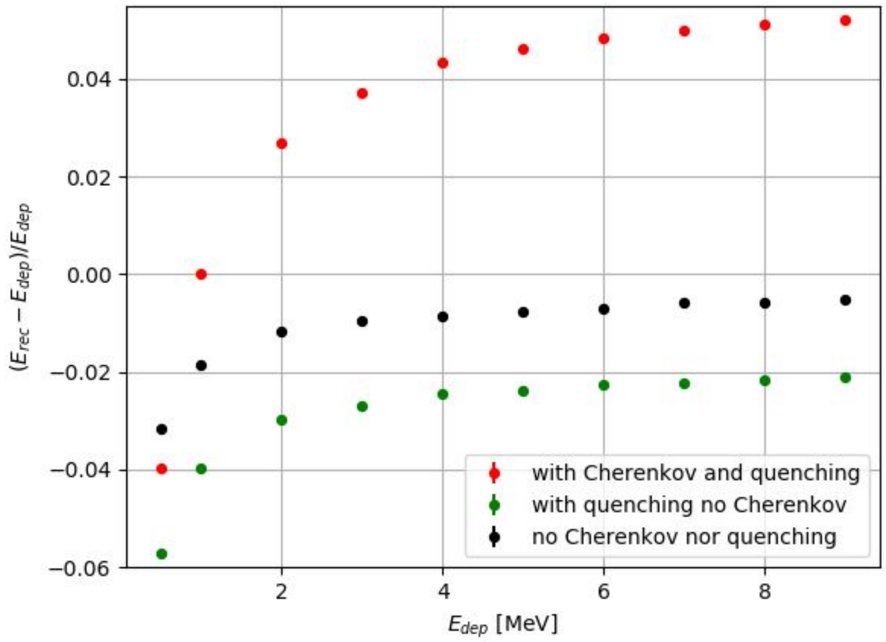
Energy resolution @ 1MeV: (2.80 ± 0.04) %

Energy resolution @ 1.022MeV: (2.80 ± 0.04) %

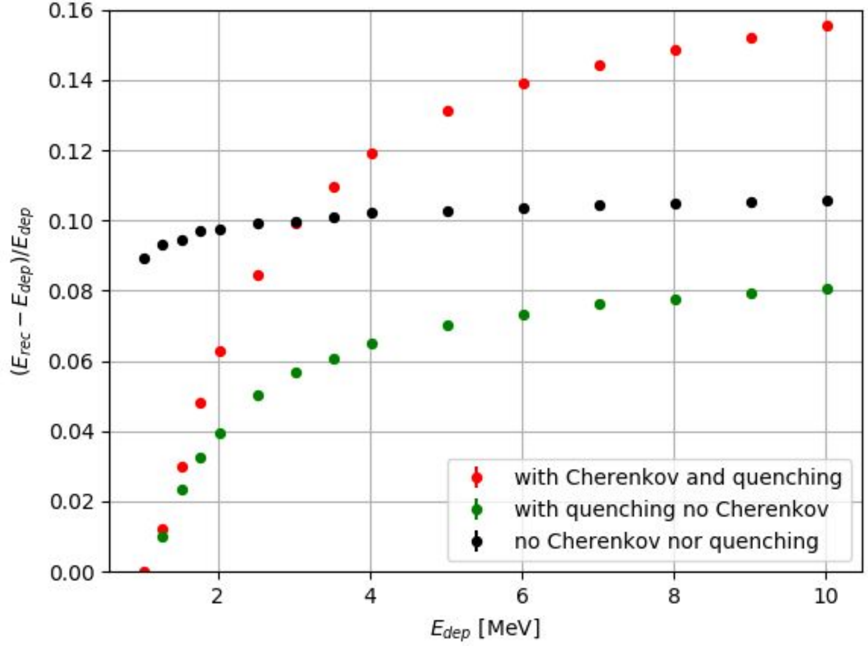
Energy resolution @ 1.022MeV: (3.17 ± 0.05) %

TURNING ON THE CHERENKOV EFFECT

Electrons



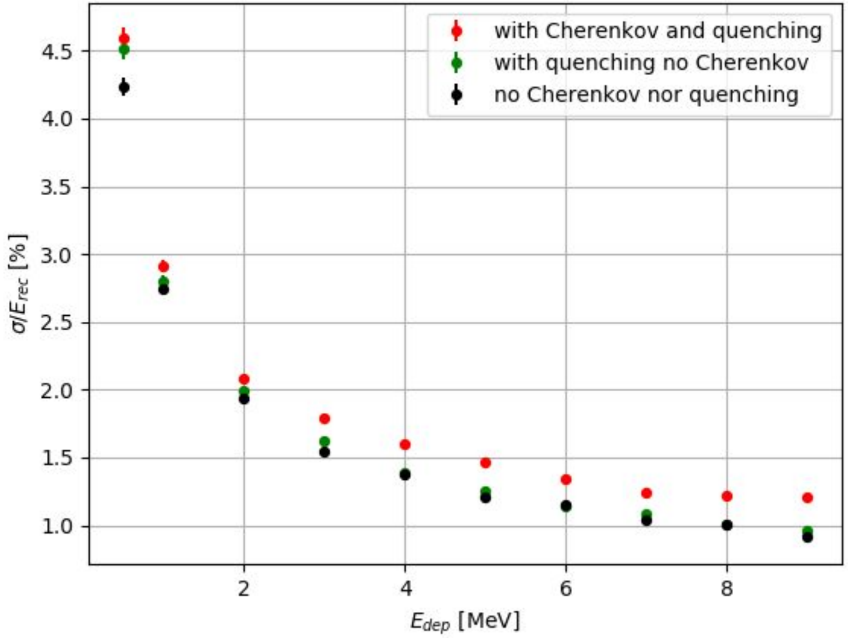
Positrons



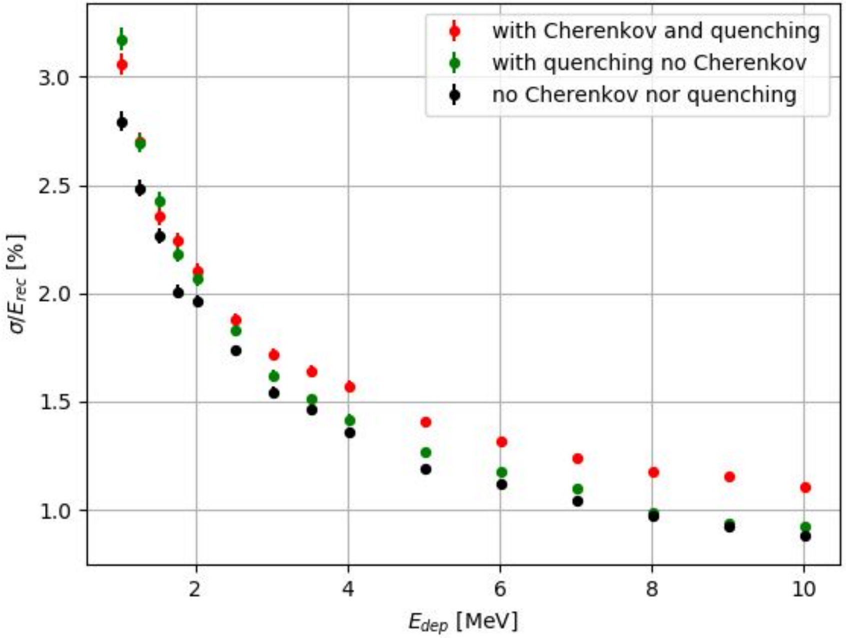
The Cherenkov has a great impact on the linearity of the reconstructed energy

TURNING ON THE CHERENKOV EFFECT

Electrons



Positrons



Energy resolution @ 1MeV: (2.74 ± 0.04) %
Energy resolution @ 1MeV: (2.80 ± 0.04) %
Energy resolution @ 1MeV: (2.91 ± 0.05) %

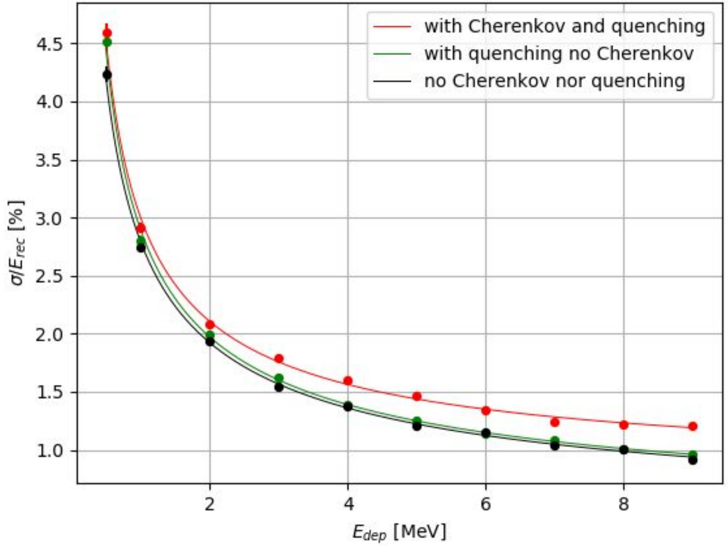
Energy resolution @ 1.022MeV: (2.80 ± 0.04) %
Energy resolution @ 1.022MeV: (3.17 ± 0.05) %
Energy resolution @ 1.022MeV: (3.05 ± 0.03) %

FITTING THE ENERGY RESOLUTION RESULTS

The resolution results were fitted with the usual function:

$$\frac{\sigma}{E_{rec}} = \sqrt{\left(\frac{a}{\sqrt{E_{dep}}}\right)^2 + b^2 + \left(\frac{c}{E_{dep}}\right)^2}$$

Electrons

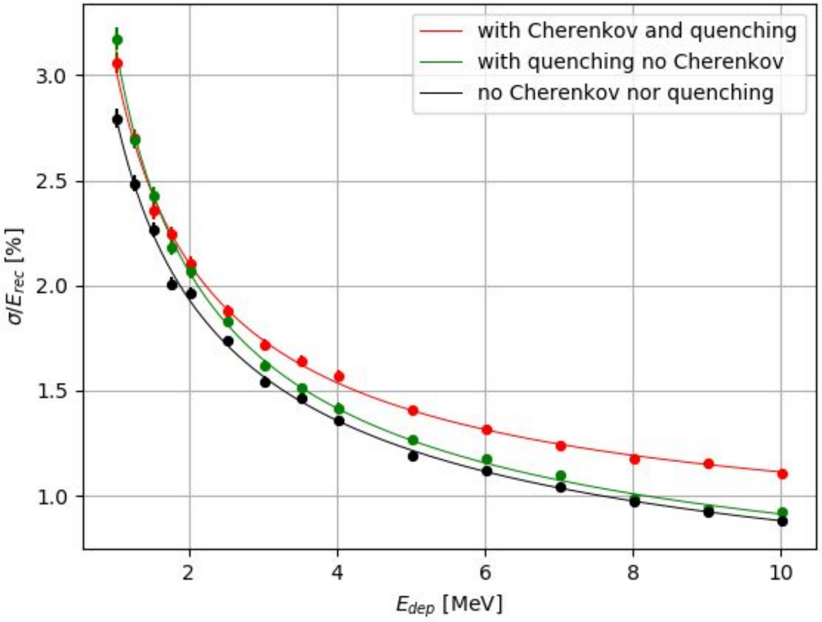


Energy resolution @ 1MeV: (2.74 ± 0.04) %
a = 2.57 ± 0.07 b = 0.36 ± 0.07 c = 1.04 ± 0.13

Energy resolution @ 1MeV: (2.80 ± 0.04) %
a = 2.59 ± 0.07 b = 0.40 ± 0.06 c = 1.24 ± 0.11

Energy resolution @ 1MeV: (2.91 ± 0.05) %
a = 2.61 ± 0.11 b = 0.80 ± 0.05 c = 1.25 ± 0.17

Positrons



Energy resolution @ 1.022MeV: (2.80 ± 0.04) %
a = 2.59 ± 0.06 b = 0.31 ± 0.06 c = 1.11 ± 0.17

Energy resolution @ 1.022MeV: (3.17 ± 0.05) %
a = 2.59 ± 0.07 b = 0.36 ± 0.06 c = 1.79 ± 0.14

Energy resolution @ 1.022MeV: (3.05 ± 0.03) %
a = 2.60 ± 0.07 b = 0.74 ± 0.03 c = 1.43 ± 0.17

Results comparable with the technote doc-DB: **7494**

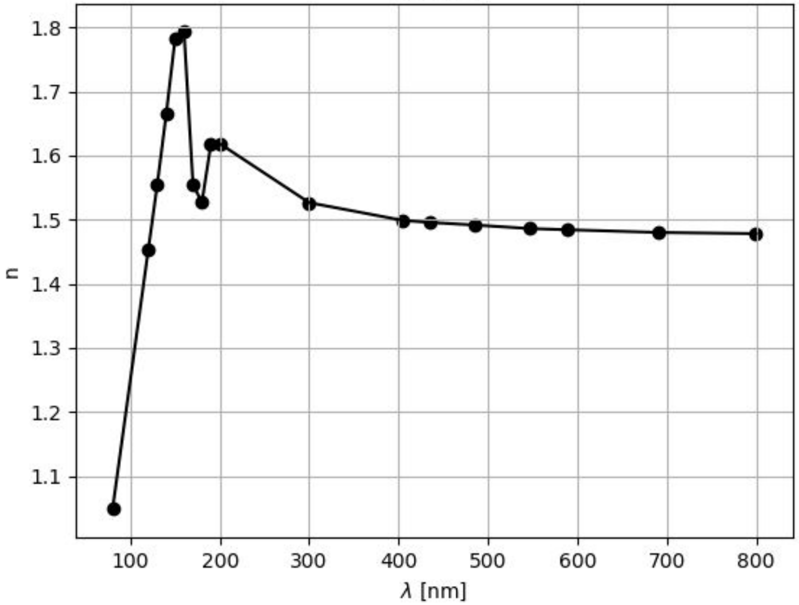
Turning on the **quenching** → The resolution at **low energy worsens** → **c increases**

Turning on the **Cherenkov** → The resolution at **high energy worsens** → **b increases**

THE CHERENKOV YIELD FACTOR

Another user-modifiable **parameter** is the **Cherenkov yield factor fC**

In G4, the refractive index is needed to generate Cherenkov photons

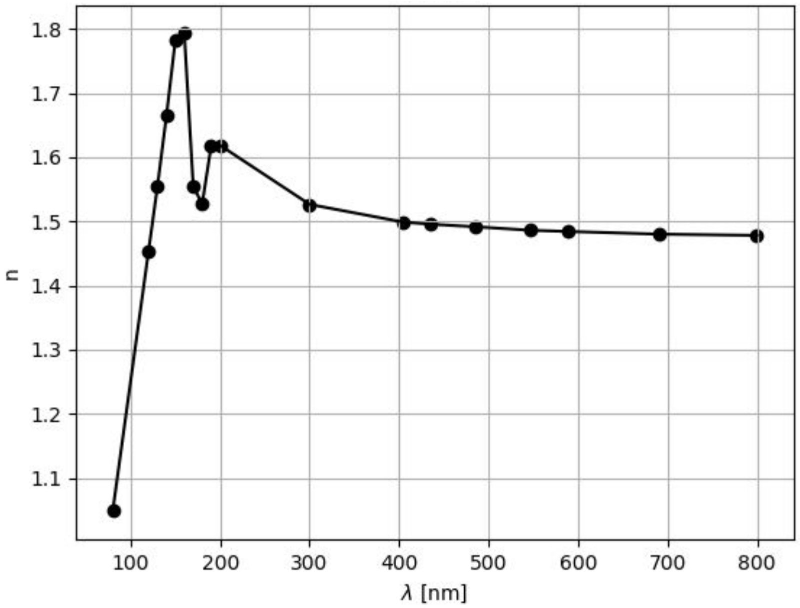


We insert the n in the range 80-800nm → **Only 80-800nm** Cherenkov **photons** are generated

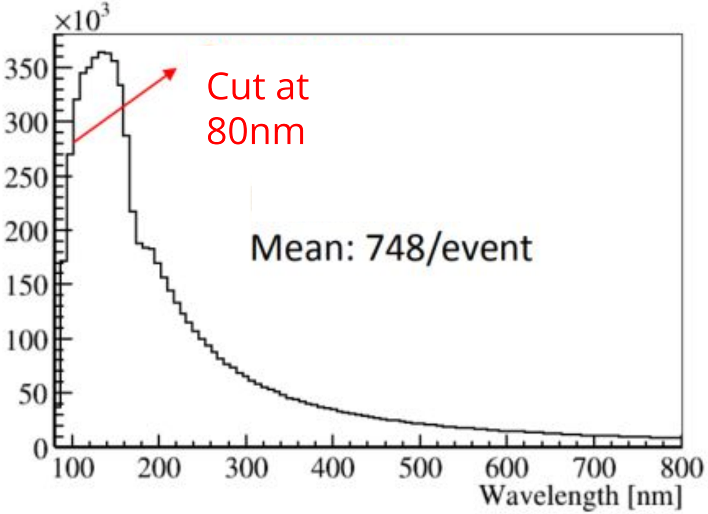
In each step, the particle emits Cherenkov photons according to Frank-Tamm law:

$$\frac{\partial^2 N}{\partial x \partial \lambda} = \frac{2\pi\alpha}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right)$$

THE CHERENKOV YIELD FACTOR



Cherenkov spectrum for a **1MeV e-** event

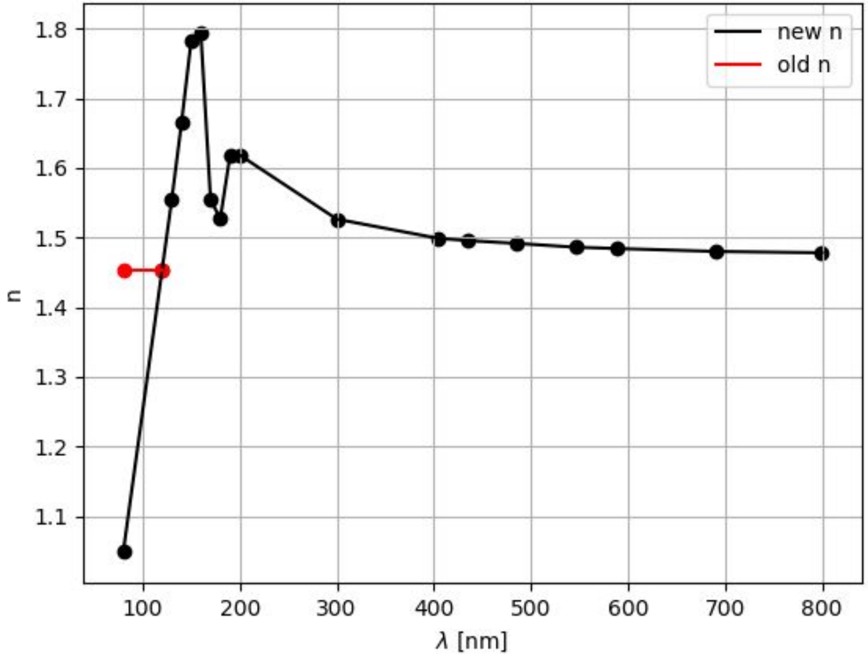


plot from docDB: 8400

$$\frac{\partial^2 N}{\partial x \partial \lambda} = \frac{2\pi\alpha}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right)$$

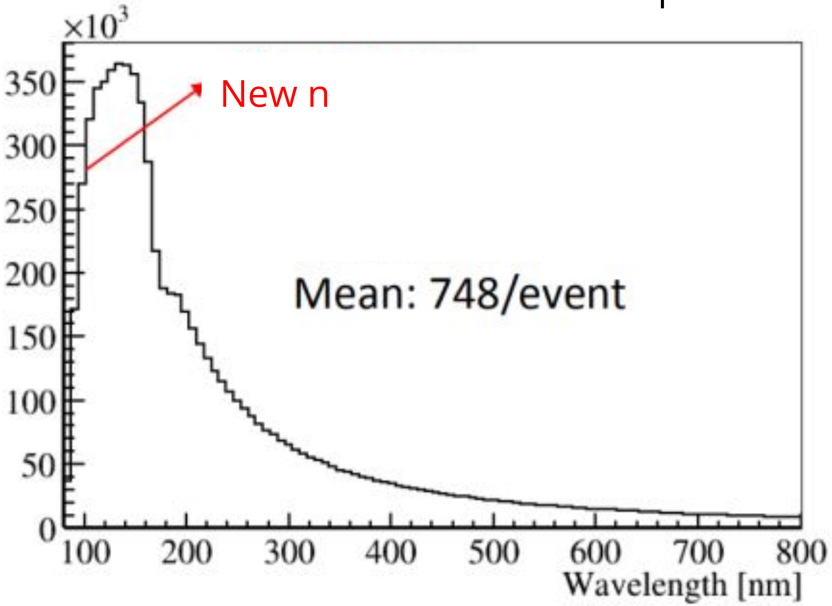
THE CHERENKOV YIELD FACTOR

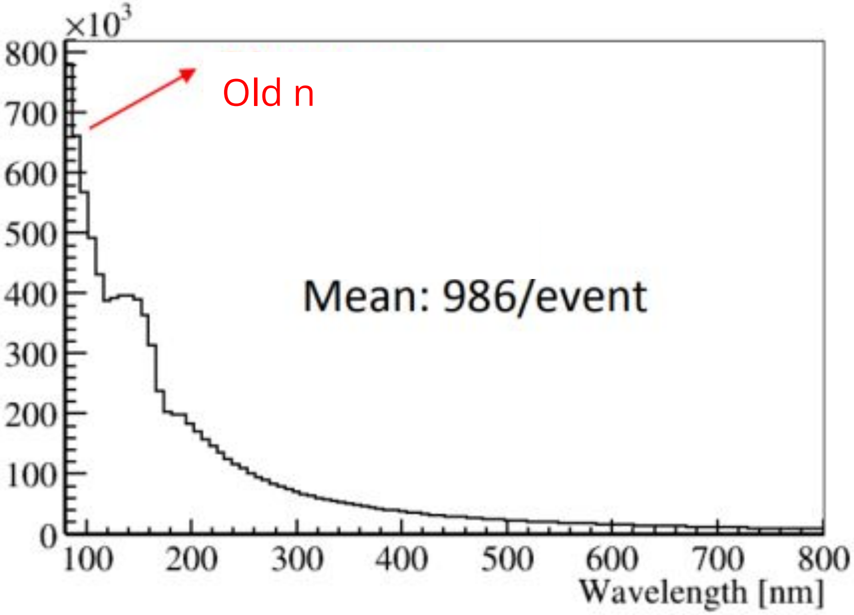
There are huge uncertainties on the refractive index at low wavelengths:



THE CHERENKOV YIELD FACTOR

Cherenkov spectrum for a **1MeV e-** event





plots from docDB: 8400

Large uncertainties in the numbers of Cherenkov photons generated

THE CHERENKOV YIELD FACTOR

We parametrize our ignorance on the number of emitted Cherenkov photons with the Cherenkov yield factor fC

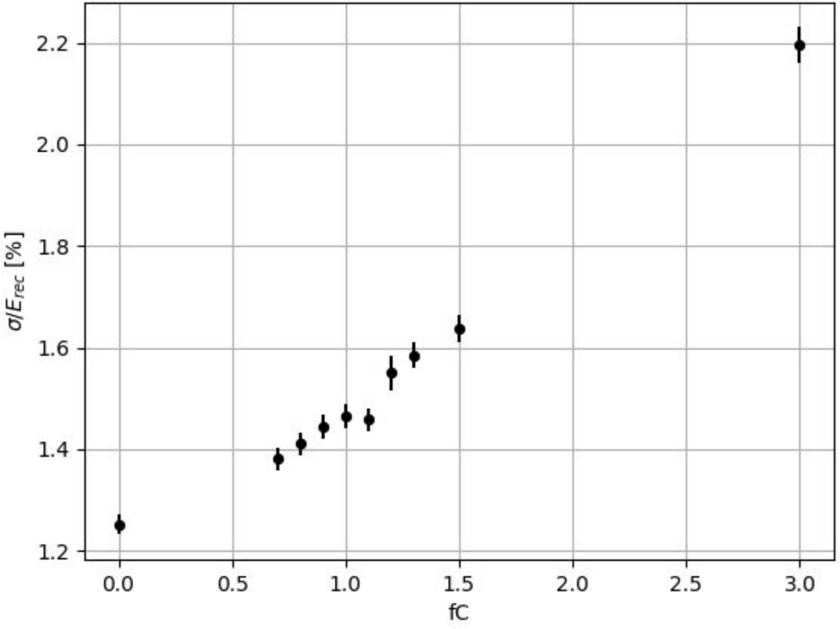
$$fC = \frac{N_{ceren}^{SNiPER}}{N_{ceren}^{G4}}$$

from the usual Franck-Tamm $d^2N/(dxd\lambda)$ formula

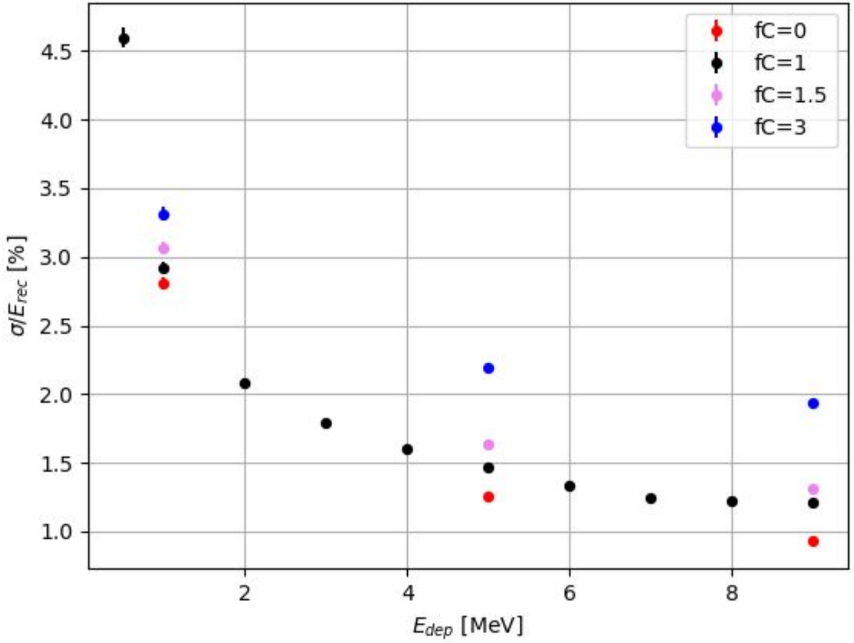
fC default value: 1

THE IMPACT OF fC ON THE ENERGY RESOLUTION

E(e-) = 5MeV

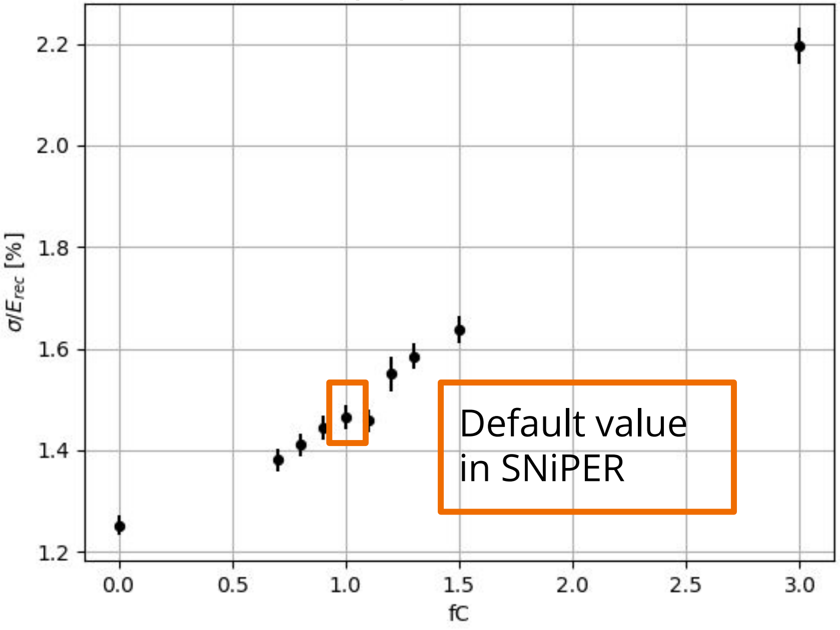


Electrons resolution studies

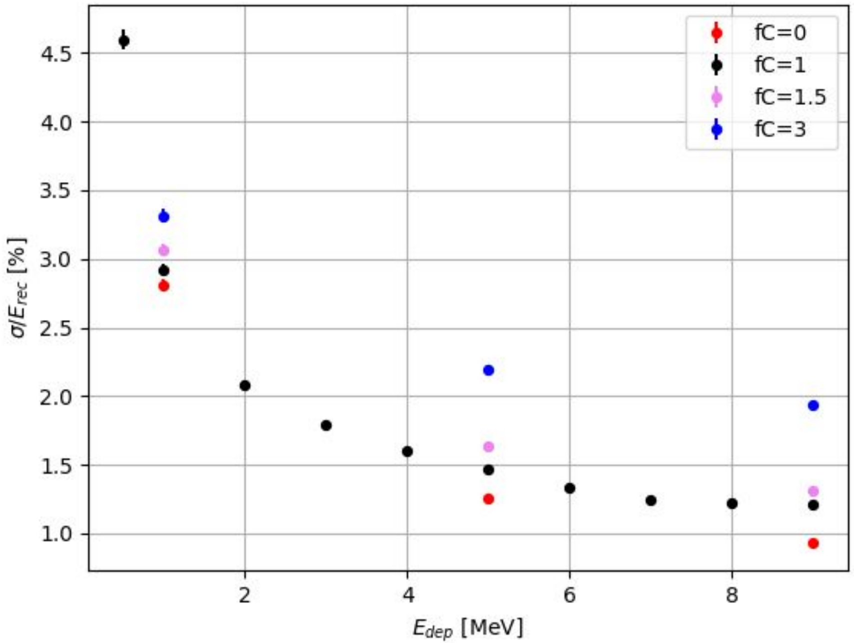


THE IMPACT OF fC ON THE ENERGY RESOLUTION

E(e-) = 5MeV

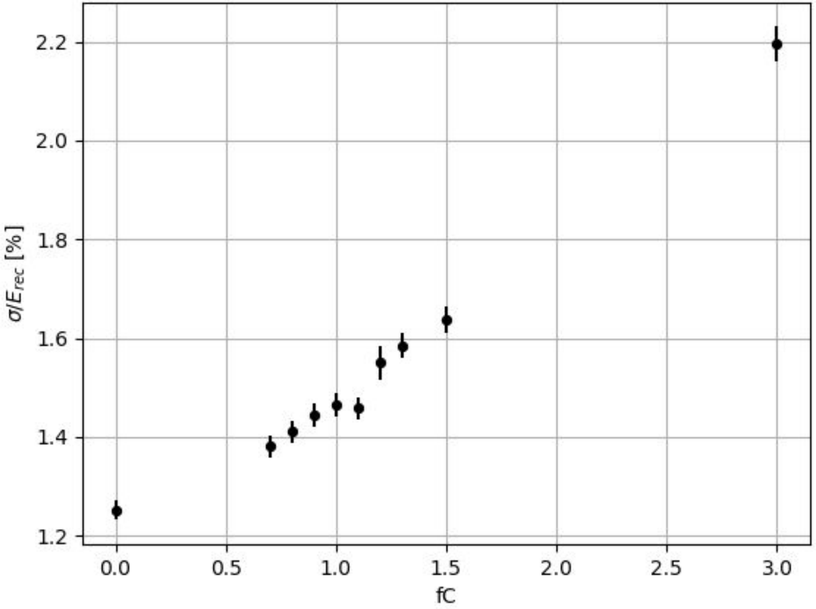


Electrons resolution studies

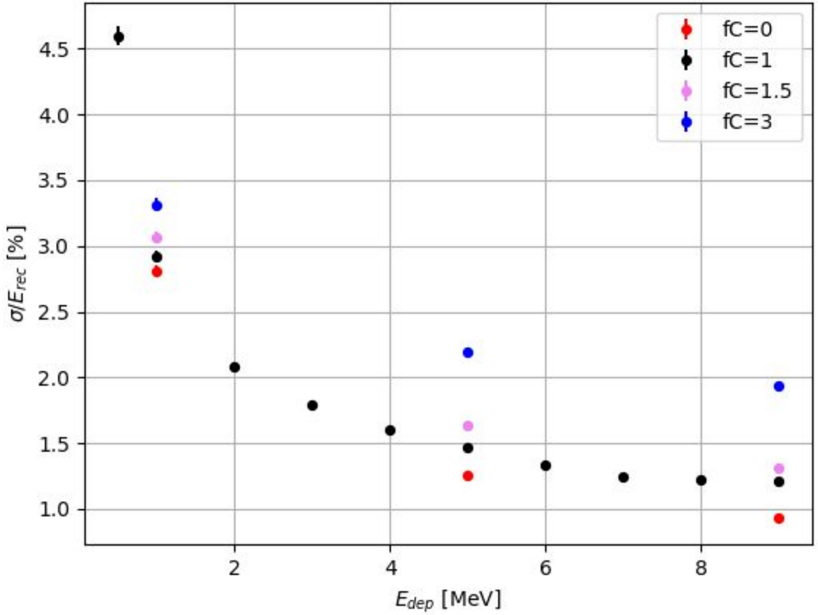


THE IMPACT OF fC ON THE ENERGY RESOLUTION

E(e-) = 5MeV



Electrons resolution studies



An **increasing fC worsens the energy resolution** → It is **crucial** to know **the Cherenkov contribution** → **SHELDON** will be useful (**n_{LS}, Cherenkov ratio**)

GOAL OF THE STUDIES

Study the **impact** of the **LS parameters** and LS **physical processes** on the simulations for **NMO**

Understand how **SNiPER works**

- **Where** the LS **parameters and physical processes** are implemented
- **How** to **modify** the default parameters

Study the **impact** of LS parameters and processes on the **energy resolution**

- Study the **impact** of the **quenching** and the **Cherenkov** effect
- Insert **SHELDON** and SHELDON-REWIND **parameters**

SHELDON PARAMETERS IN SNIPER

The majority of the **data** has **not been changed** in a **few years** or are inherited from Daya Bay.

↓

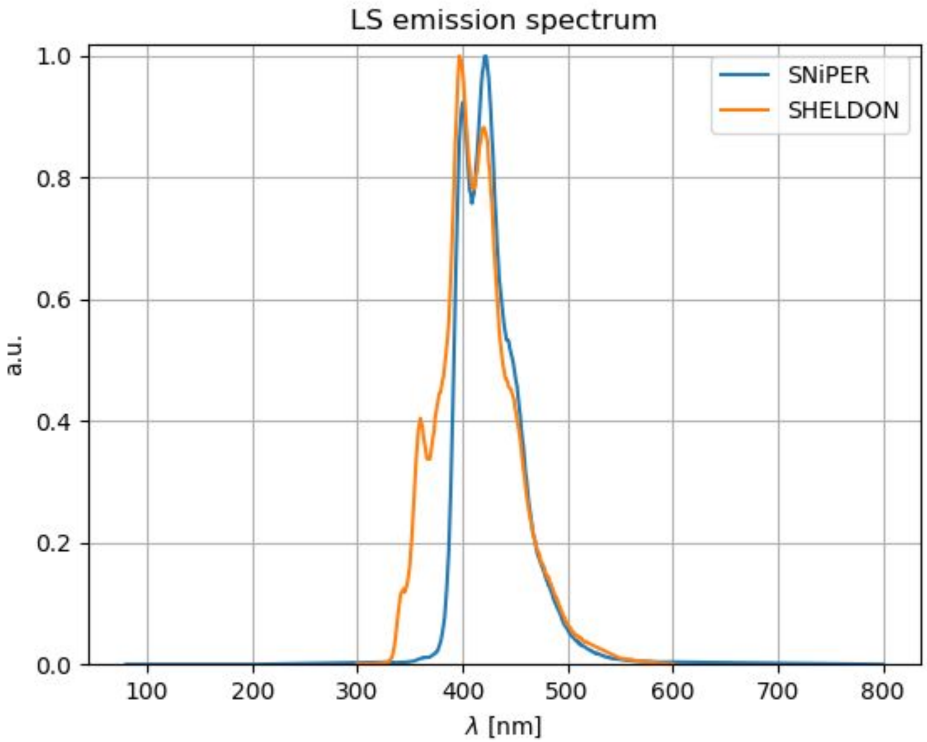
It would be interesting to **insert** in SNiPER the newly measured **LS parameters**:

SHELDON → **emission spectrum, fluorescence times and Cherenkov ratio;**

SHELDON-REWIND → **refractive index** (to be measured);

GOAL: determine if there are significative differences in energy reconstruction or reconstruction (crucial for NMO) with the new parameters.

SHELDON EMISSION SPECTRUM



SIMILARITIES:

- Double peak, 1st at ~400nm, 2nd at ~425nm;
- Very similar descending profiles after the second peak.

DIFFERENCES:

- Main peak;
- Different ascending profile.

SNiPER spectrum is extremely outdated

We **suggest** to **update** the **SNiPER file** with the newly measured emission spectrum

SHELDON SCINTILLATION PARAMETERS

SNiPER parameters

PARTICLE	τ_1 [ns] / ratio	τ_2 [ns] / ratio	τ_3 [ns] / ratio	τ_4 [ns] / ratio
e^-, e^+, γ	4.6 / 70.7%	15.1 / 20.5%	76.1 / 6.0%	397 / 2.8%
p, n	4.5 / 61.4%	15.7 / 23.2%	76.2 / 9.0%	367 / 6.4%
α	4.345 / 49.82%	17.64 / 27.39%	89.045 / 14.67%	544.48 / 8.12%

e- and p fluorescence times from Munich group, 2021

SHELDON parameters

PARTICLE	τ_1 [ns] / ratio	τ_2 [ns] / ratio	τ_3 [ns] / ratio	τ_4 [ns] / ratio
e^-, e^+, γ	3.96 / 65.02%	15.11 / 23.72%	85.0 / 7.26%	549 / 4.27%
p, n	4.60 / 62.02%	18.99 / 21.07%	108.2 / 9.94%	691 / 6.97%
α	4.79 / 55.97%	20.86 / 23.15%	103.8 / 13.17%	633 / 8.50%

SHELDON SCINTILLATION PARAMETERS

SNiPER parameters

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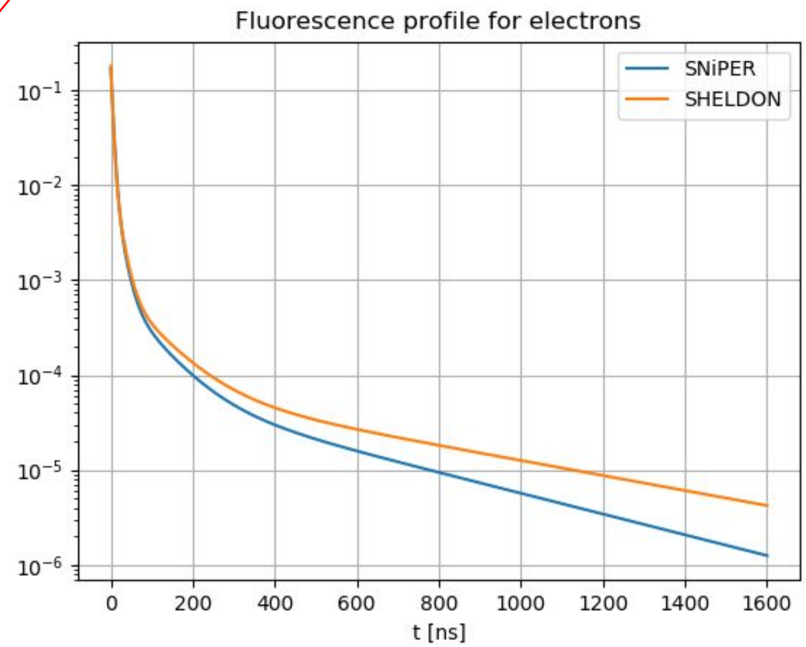
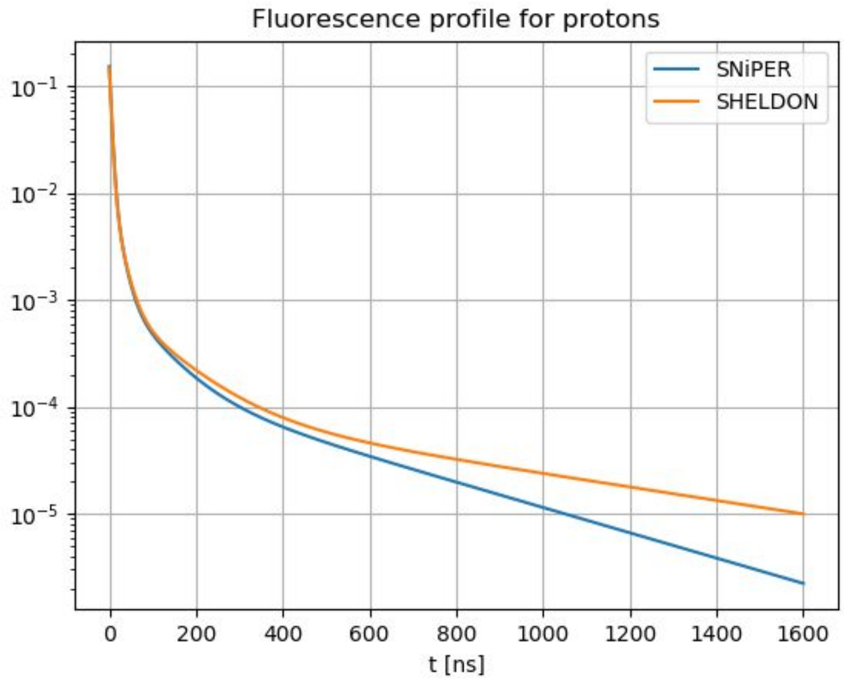
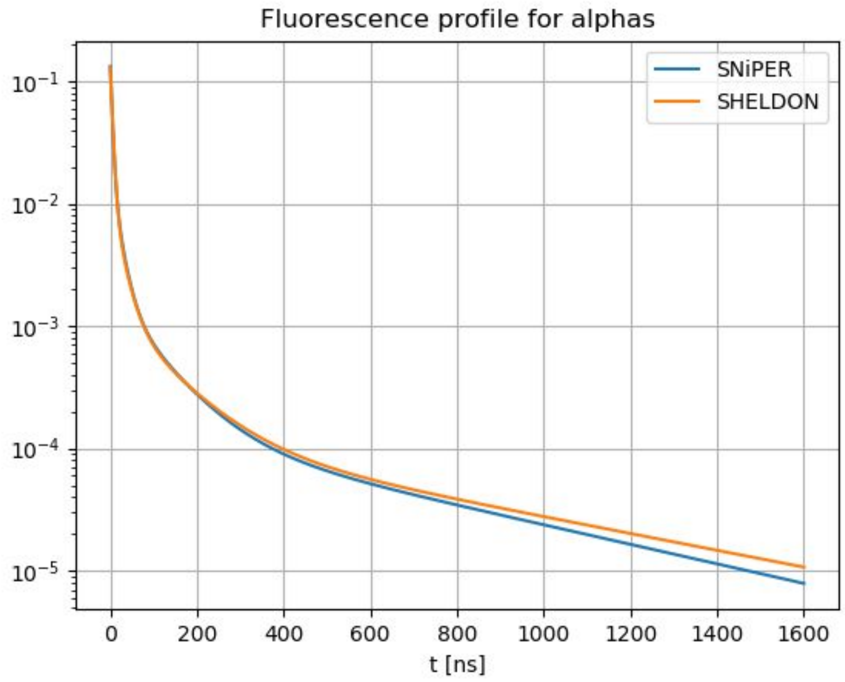
α	4.79 / 55.97%	20.86 / 23.15%	103.8 / 13.17%	633 / 8.50%

τ_4(SHELDON) > τ_4(SNiPER)
q_4(SHELDON) > q_4(SNiPER)



SHELDON SCINTILLATION PARAMETERS





SHELDON AND MUNICH SCINTILLATION PARAMETERS

Sheldon's acquisition time is 1.6μs, Munich's acquisition time is ~ half ;

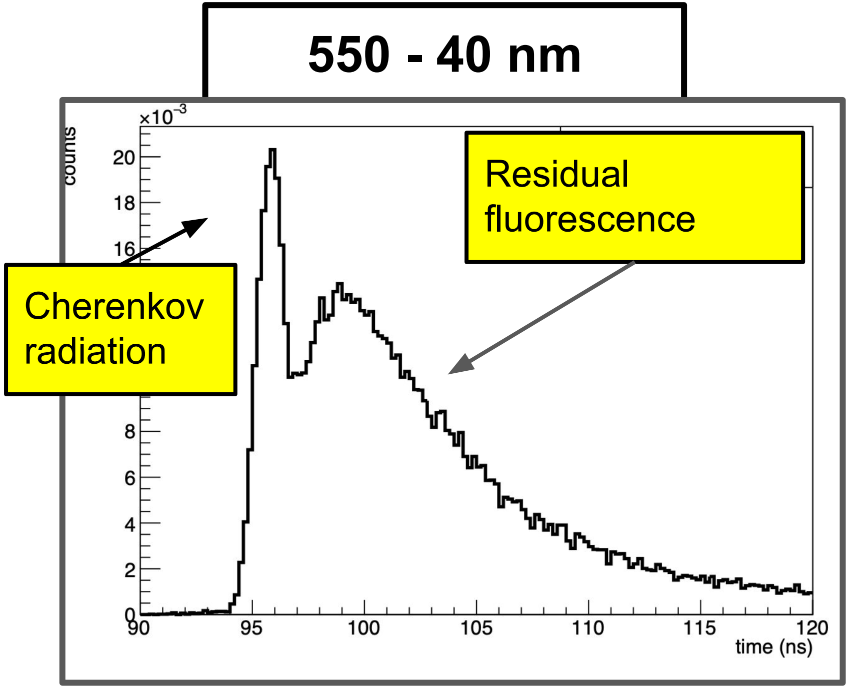
We have to discuss which parameters are more reliable;

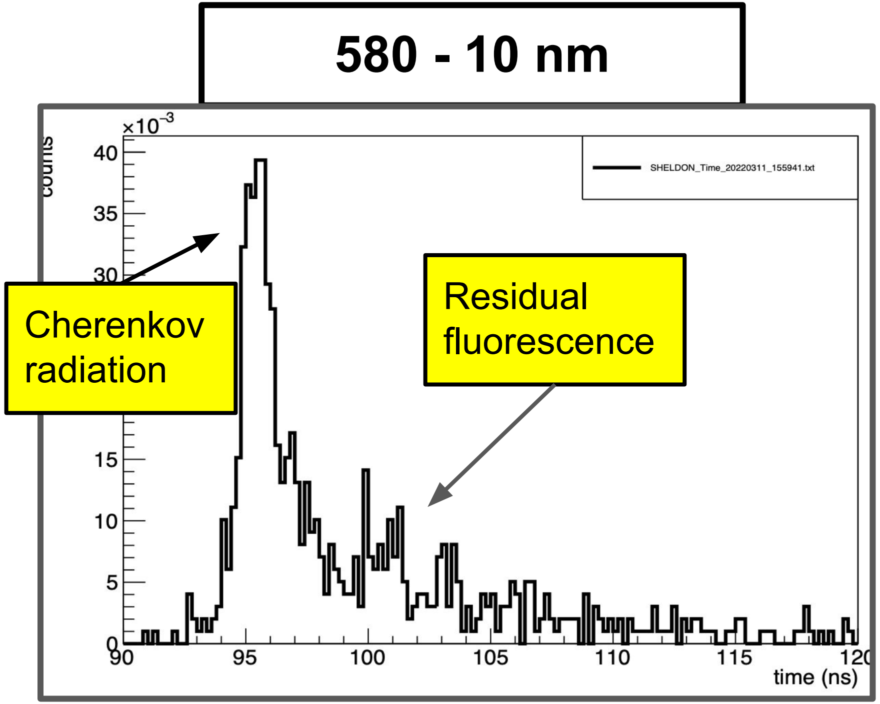
SHELDON will test its fluorescence times applying a muon veto;

IN THE MEANTIME: we could study the impact of the different parameters in SNiPER simulation

SHELDON'S CHERENKOV RATIO

In SHELDON we are studying the Cherenkov ratio at two different wavelengths (see Marco Beretta's presentation on Monday):





SHELDON'S CHERENKOV RATIO

We are building a **MC simulation of SHELDON** using **SNiPER framework** (SHELDON-SNIPER).

Confronting SHELDON's experimental results with **SHELDON-SNIPER** simulation we could get **useful information** on the parameter **fC**

CONCLUSIONS

Known:

- **Where and how** all the **LS parameters** are implemented in **SNiPER** and how to **modify** their **default values**;
- The **impact** of the **quenching** and the **Cherenkov effect** on the energy reconstruction and resolution;

To study:

- The impact of the **absorption/re-emission** and **scattering** as well (not so easy to turn/off in J22);
- The **impact** of inserting **SHELDON's parameters** in SNiPER;
- Creation of a **MC simulation of SHELDON** using SNiPER-framework.

BACKUP

WHERE TO FIND THE PARAMETERS FILES

From the version J21v1r0-Pre1 a huge offline database is present here:

/data/Simulation

The properties of the phototubes can be found here:

/data/Simulation/PMTProperty

The properties of all the other materials can be found here:

/data/Simulation/Material

THE MATERIALS PARAMETERS IN SNiPER

All the other LS parameters must be changed in SNiPER

A huge database for all the materials is present

A FEW COMPLICATIONS

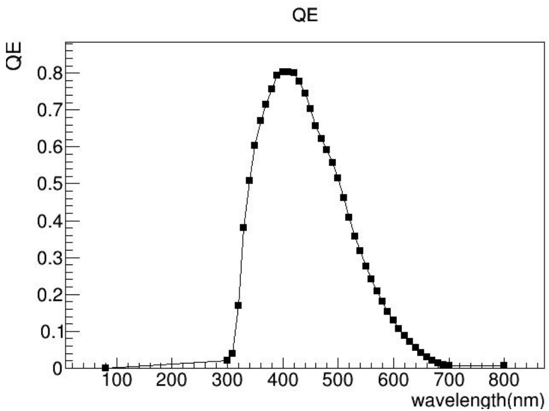
To change all these parameters it is necessary to modify the files in the database. **BUT:**

- The values found in the files need sometimes to be multiplied by scale factors present in other files

```
RayleighLenBefore 42.0
RayleighLenAfter  27.0
```

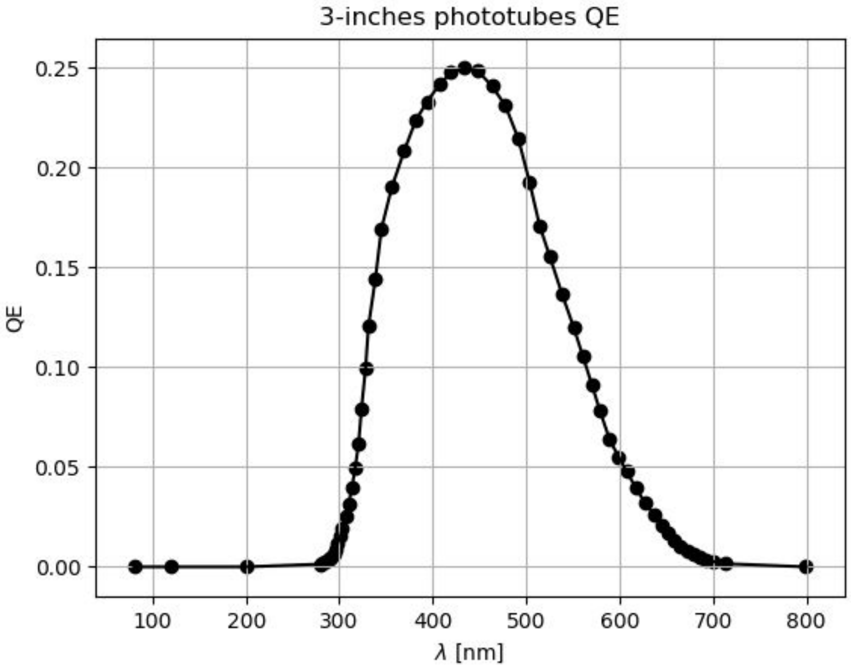
```
AbsorptionLenBefore 26.0
AbsorptionLenAfter  77.0
```

- There are some outdated files and invalid ones:

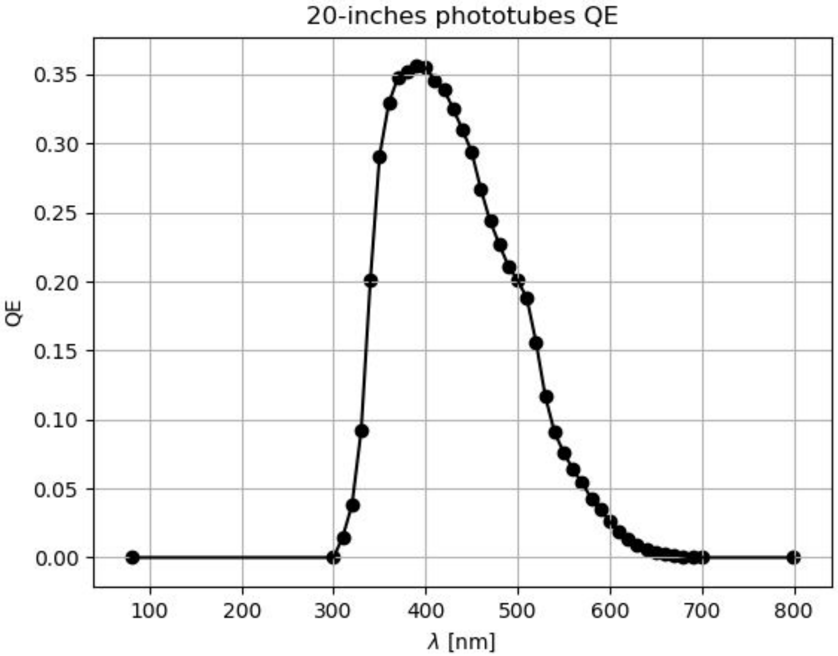


Peak value of QE is ~0.8
⇒ Definitely not correct!
⇒ **Wrong file**

A FEW COMPLICATIONS



Peak value of ~0.25 at 425nm



Peak value of ~0.35 at 400nm

Plots from the JUNOwiki page
Correct PMT MC implementation found with the help of Hu Yuxiang

THE USER-MODIFIABLE PARAMETERS

Few parameters are easily modifiable by the SNiPER user:

The **“constant properties”**:

- ➔ The LS **light-yield** (default value: 9507 photons/MeV);
- ➔ The **Birks’ constants** (default values: $kB=6.5 \cdot 10^{-3}$g/cm2/MeV, $kC=1.5 \cdot 10^{-6}$(g/cm2/MeV)^{2});

The **optical models**:

- ➔ Choose between an “old” or “new” **LS model** (default: old);
- ➔ Choose between an “old” or “new” **PMT model** (default: new);

Tune the **physical processes**:

- ➔ Disable quenching effect;
- ➔ Disable the Cherenkov effect;
- ➔ Change the Cherenkov yield factor **fC** (default 1).

HOW TO MODIFY THE PARAMETERS

How to modify the LY (to ex. 10000/MeV)**:**

python tut_detsim.py --replace-param Material.LS.ConstantProperty.ScintillationYield:10000/MeV gun [...]

How to modify the Birks constants:

python tut_detsim.py --replace-param Material.LS.ConstantProperty.BirksConstant1:12.05e3*g/cm2/MeV,Material.LS.ConstantProperty.BirksConstant2:0 gun [...]

How to use the new LS optical model:

python tut_detsim.py gun --new-optical-model gun [...]

HOW TO MODIFY THE PARAMETERS

How to use the old PMT optical model:

python tut_detsim.py gun --disable-pmt-optical-model gun [...]

How to turn off the quenching effect:

python tut_detsim.py --no-quenching gun [...]

How to turn off the Cherenkov effect:

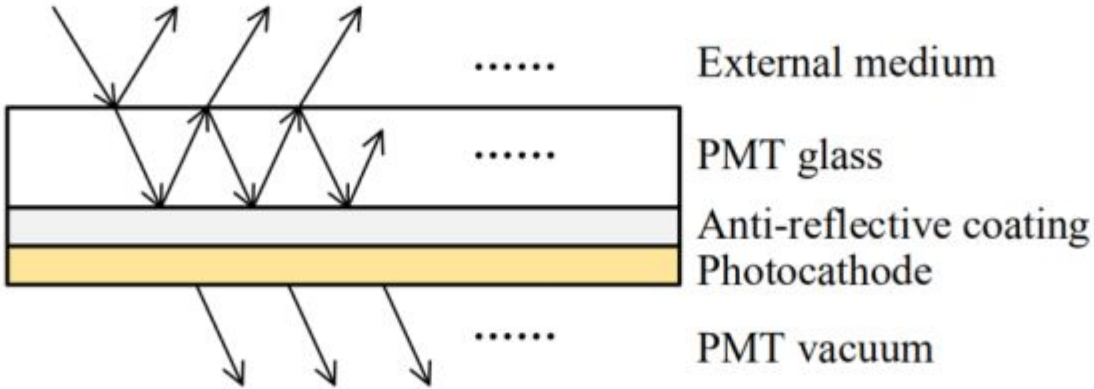
python tut_detsim.py --no-cerenkov gun [...]

How to modify the Cherenkov yield factor (to ex. 0.5)**:**

python tut_detsim.py gun --cerenkov-yield-factor 0.5 gun [...]

PMT NEW OPTICAL MODEL

sketch from
docDB:8625



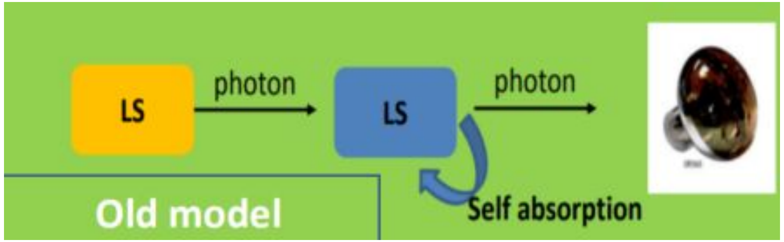
In the new model the PMT window is treated as a multilayer optical stack

LS MODELS

OLD MODEL

It considers the components **LS** as a **whole** → **one set of parameters** is used

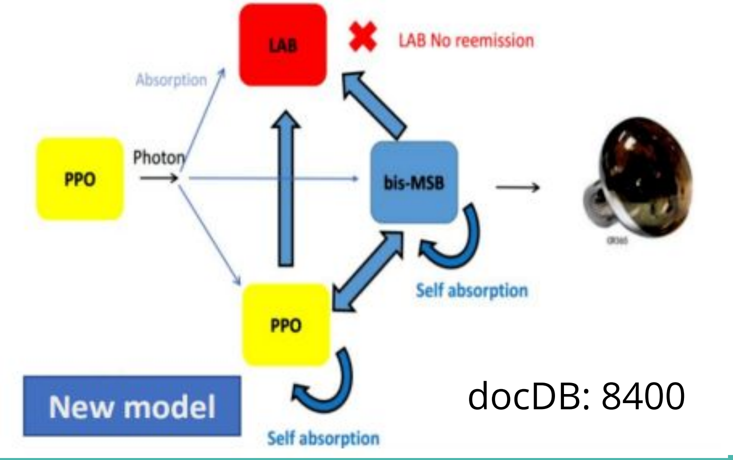
It is the **default model** in SNiPER



docDB: 8400

NEW MODEL

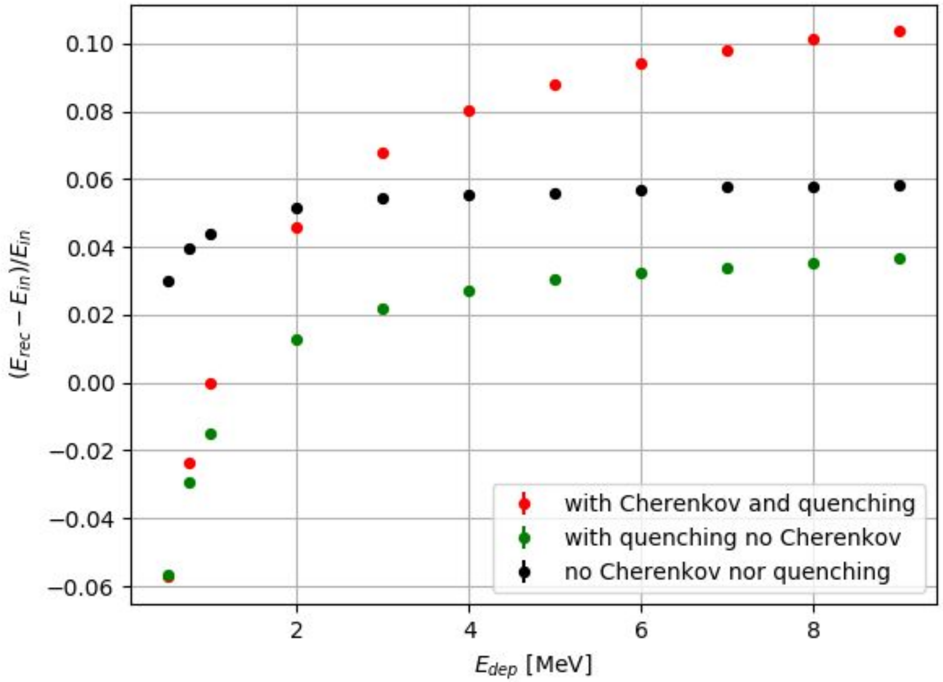
It considers the **three components** of the LS **independently** → **three sets of parameters** are used



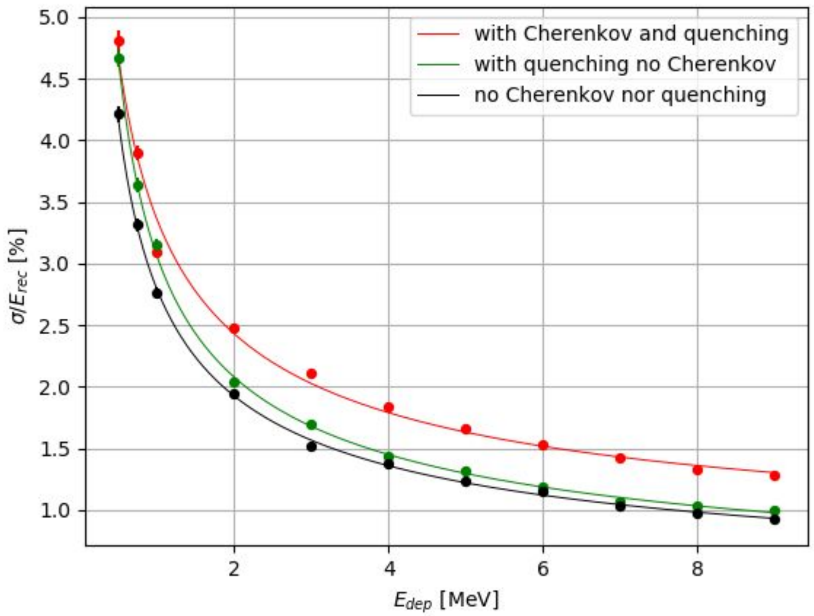
docDB: 8400

ENERGY RECONSTRUCTION RESULTS

Gammas



Gammas



Energy resolution @ 1MeV: (2.76 ± 0.04) %

a = 2.58 ± 0.06   b = 0.34 ± 0.07   c = 1.02 ± 0.12

Energy resolution @ 1MeV: (3.10 ± 0.04) %

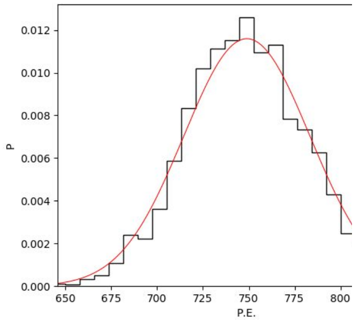
a = 2.76 ± 0.07   b = 0.29 ± 0.10   c = 1.30 ± 0.12

Energy resolution @ 1MeV: (2.91 ± 0.05) %

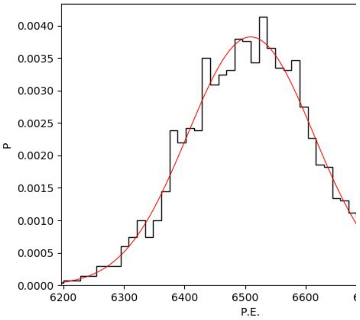
a = 3.29 ± 0.13   b = 0.70 ± 0.10   c = 0.0 ± 1.3

Reconstructed energy with Cherenkov

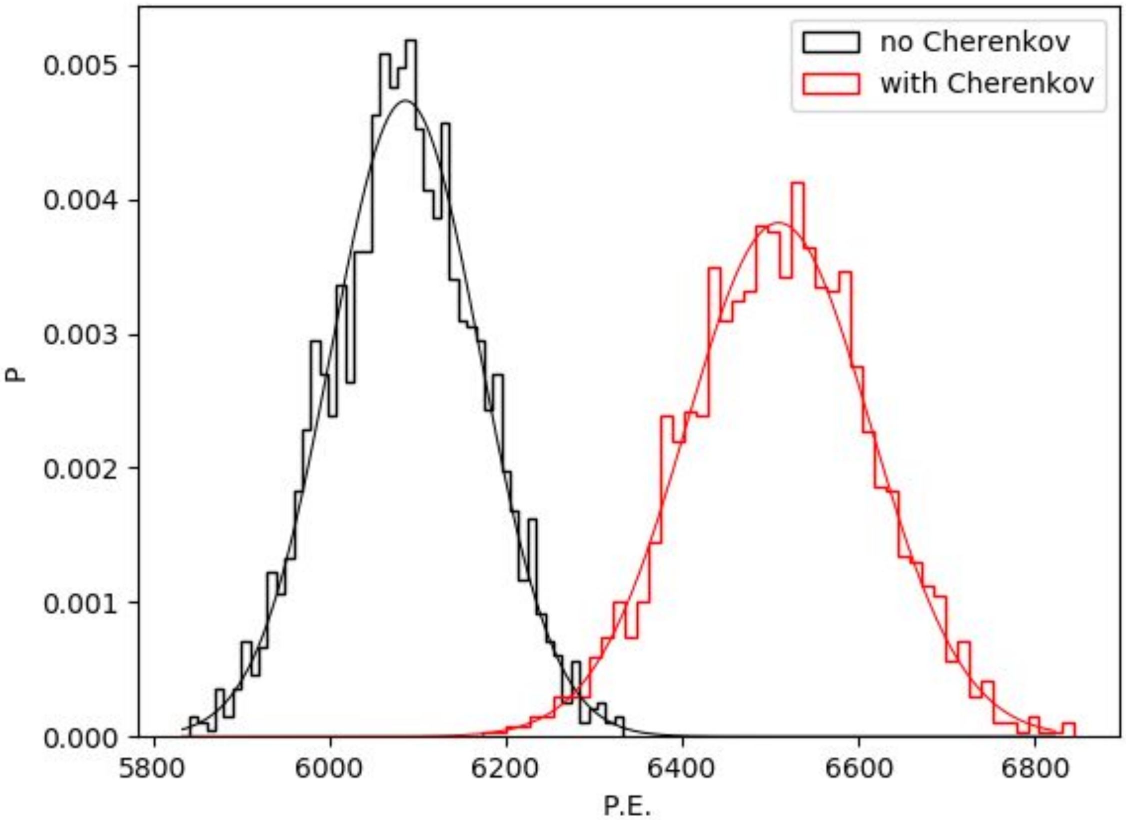
E(e-)=0.5MeV



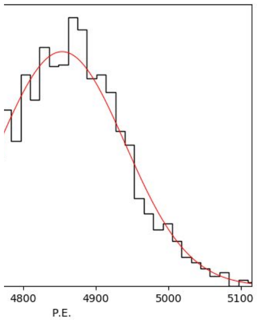
E(e-)=4MeV



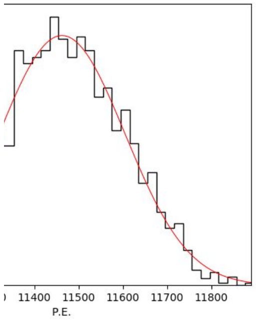
E(e-)=4MeV



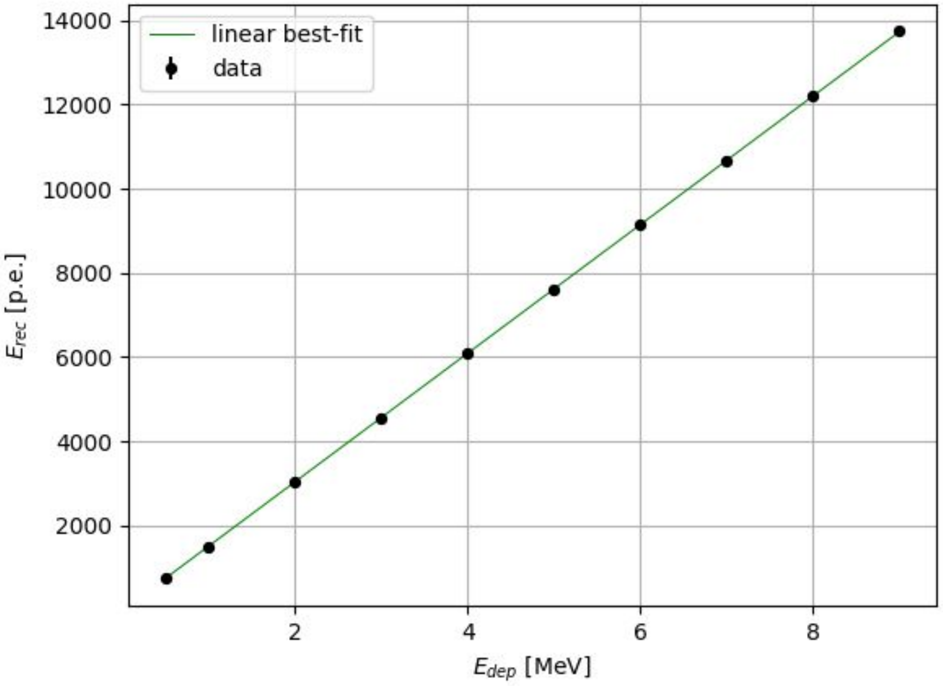
e-)=3MeV



e-)=7MeV



Electron energy reconstruction - no Cherenkov



A good linear fit can be obtained above 2MeV where the quenching is sub-dominant:

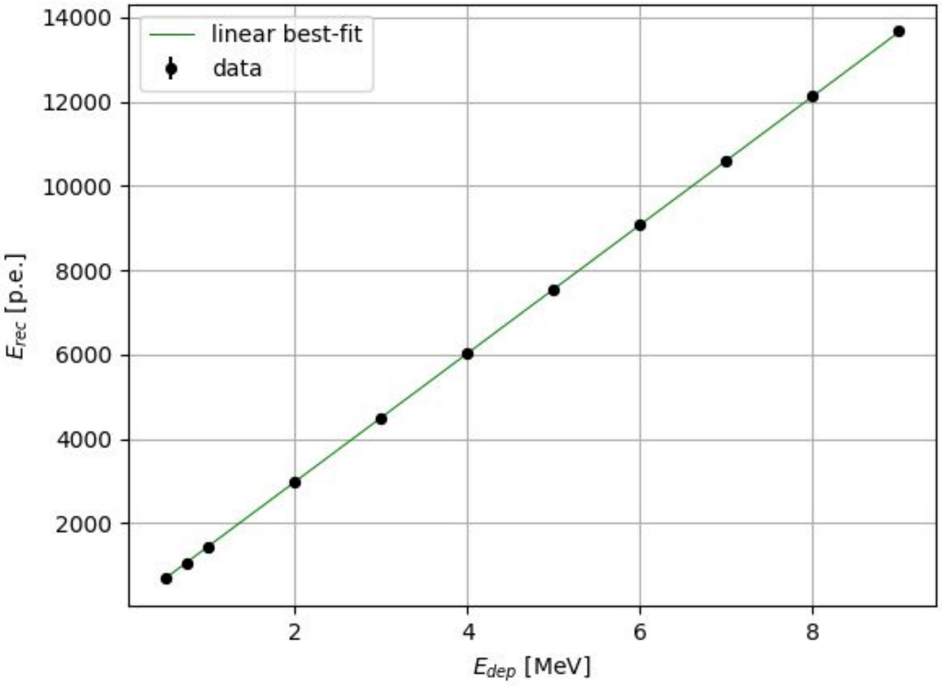
$$E_{rec} = A \cdot E_{dep} + B$$

A = 1530.2 ± 0.4
B = -35.2 ± 1.8

$\chi^2_{red} = 1.25$
$p_0 = 0.28$

E_{rec} @ 1MeV: (1497.8 ± 0.9) p.e.

Photon energy reconstruction - no Cherenkov



A good linear fit can be obtained above 2MeV where the quenching is sub-dominant:

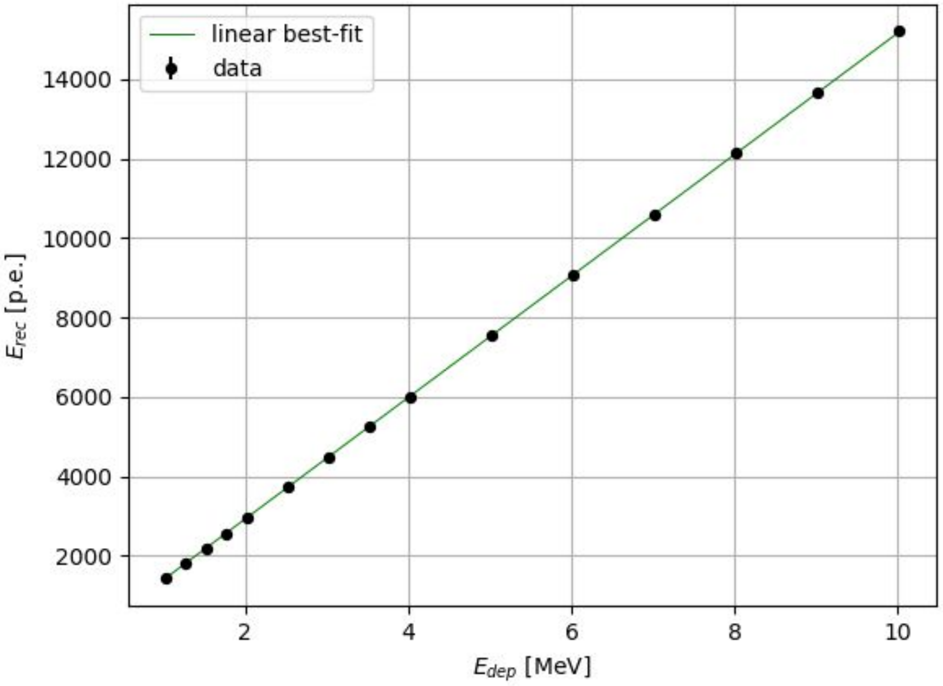
$$E_{rec} = A \cdot E_{dep} + B$$

A = 1528.1 ± 0.5
B = -90 ± 2

$\chi^2_{red} = 2.56$
$p_0 = 0.02$

E_{rec} @ 1MeV: (1443 ± 1) p.e.

Positron energy reconstruction - no Cherenkov



A good linear fit can be obtained above 2MeV where the quenching is sub-dominant:

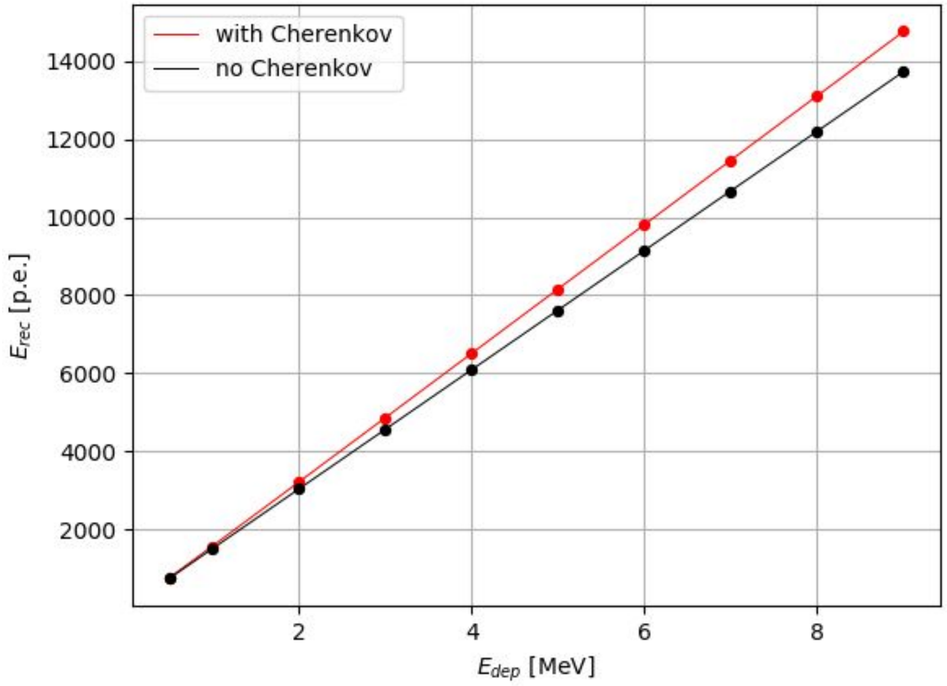
$$E_{rec} = A \cdot E_{dep} + B$$

A = 1531.0 ± 0.4 χ^2_{red} = 1.79

B = -145.9 ± 1.7 p_0 = 0.07

E_{rec} @ 1.022MeV: (1432 ± 1) p.e.

Electron energy reconstruction with Cherenkov



A good linear fit cannot be obtained!

An effective parametrization could be:

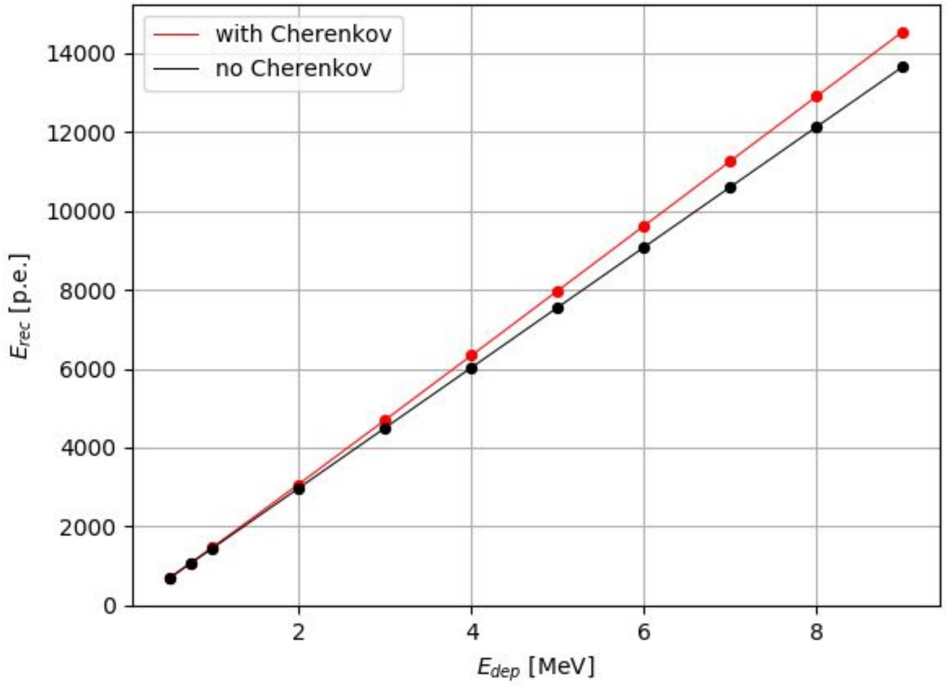
$$E_{rec} = A \cdot E^2_{dep} + B \cdot E_{dep} + C \cdot E^{0.5}_{dep} + D$$

A = -1.5 ± 0.3
B = -1695 ± 6
C = -117 ± 12
D = -15 ± 6

$\chi^2_{red} = 1.1$
$p_0 = 0.36$

E_{rec} @ 1MeV: (1559 ± 1) p.e. with Cherenkov
E_{rec} @ 1MeV: (1497.8 ± 0.9) p.e. without Cherenkov

Photon energy reconstruction with Cherenkov



A good linear fit cannot be obtained!

An effective parametrization could be:

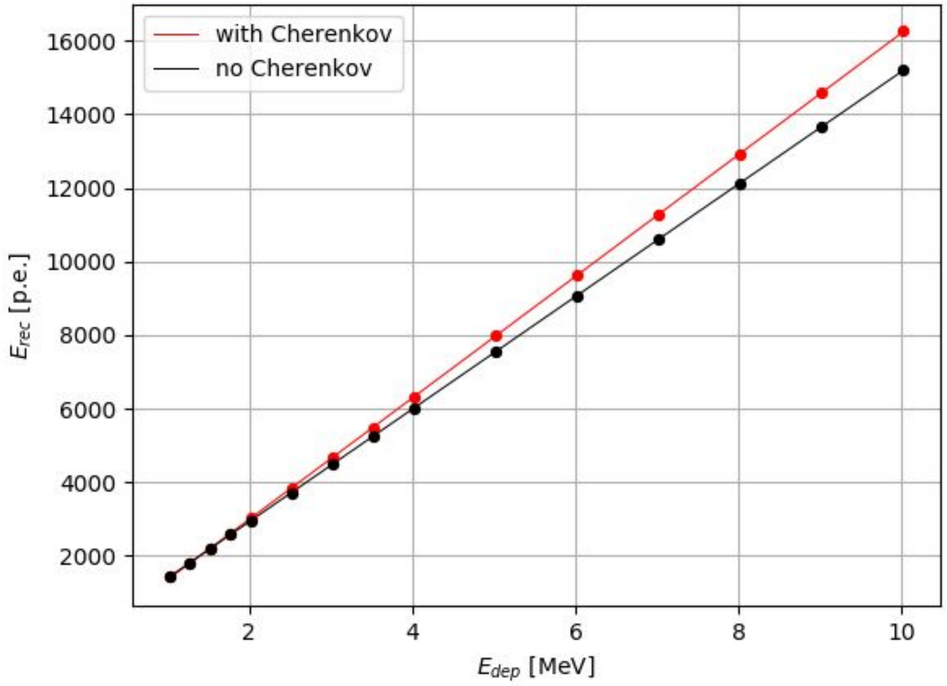
$$E_{rec} = A \cdot E^2_{dep} + B \cdot E_{dep} + C \cdot E^{0.5}_{dep} + D$$

A = -2.5 ± 0.2
B = -1741 ± 5
C = -322 ± 10
D = -47 ± 5

$\chi^2_{red} = 0.61$
$p_0 = 0.75$

E_{rec} @ 1MeV: (1465 ± 1) p.e. with Cherenkov
E_{rec} @ 1MeV: (1443 ± 1) p.e. without Cherenkov

Positron energy reconstruction with Cherenkov



A good linear fit cannot be obtained!

An effective parametrization above 2MeV could be:

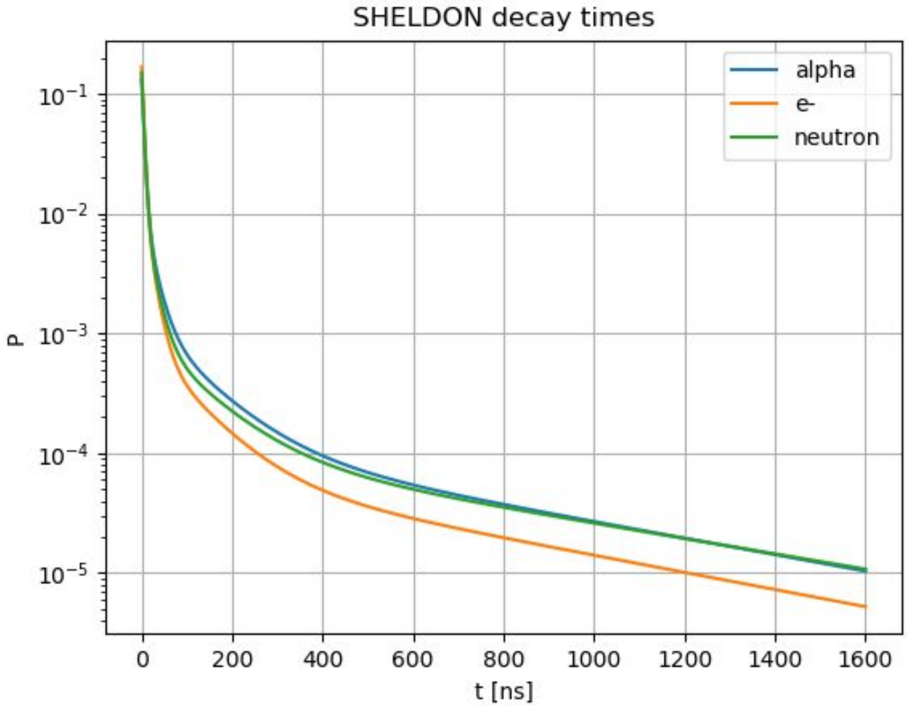
$$E_{rec} = A \cdot E^2_{dep} + B \cdot E_{dep} + C \cdot E^{0.5}_{dep} + D$$

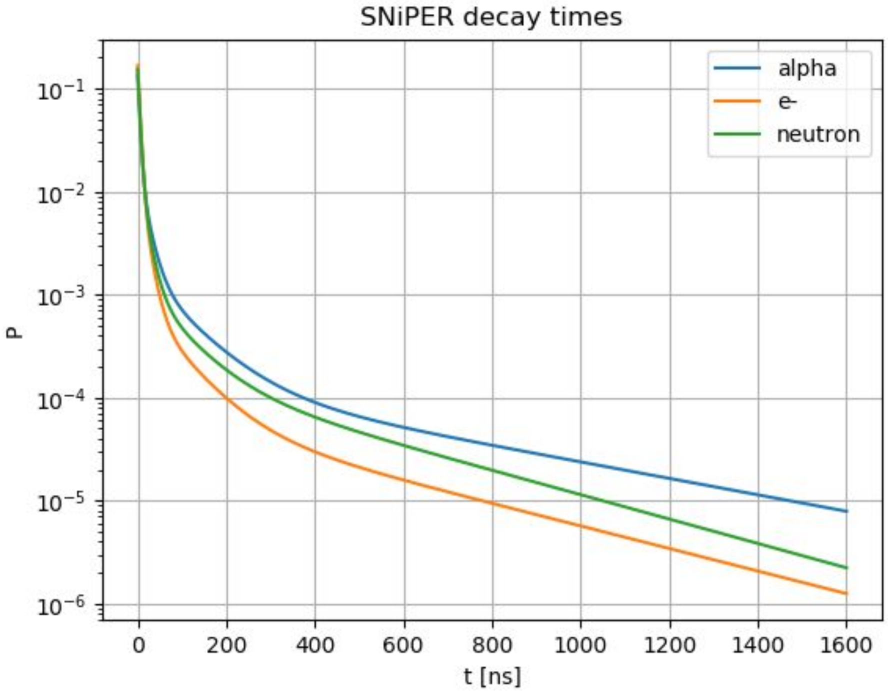
A = -0.5 ± 1.0
B = -1680 ± 30
C = -100 ± 80
D = -244 ± 70

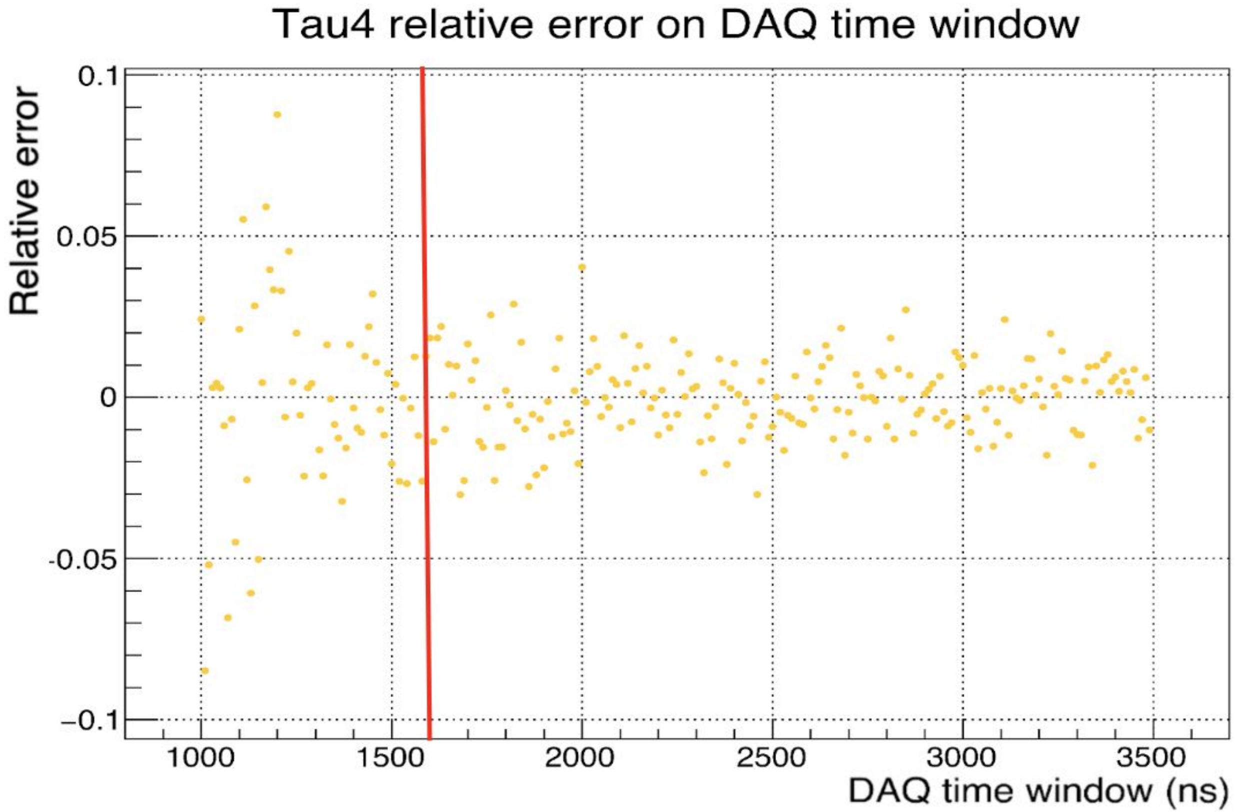
$\chi^2_{red} = 1.53$
$p_0 = 0.02$

E_{rec} @ 1.022MeV: (1434 ± 1) p.e. with Cherenkov
E_{rec} @ 1.022MeV: (1432 ± 1) p.e. without Cherenkov

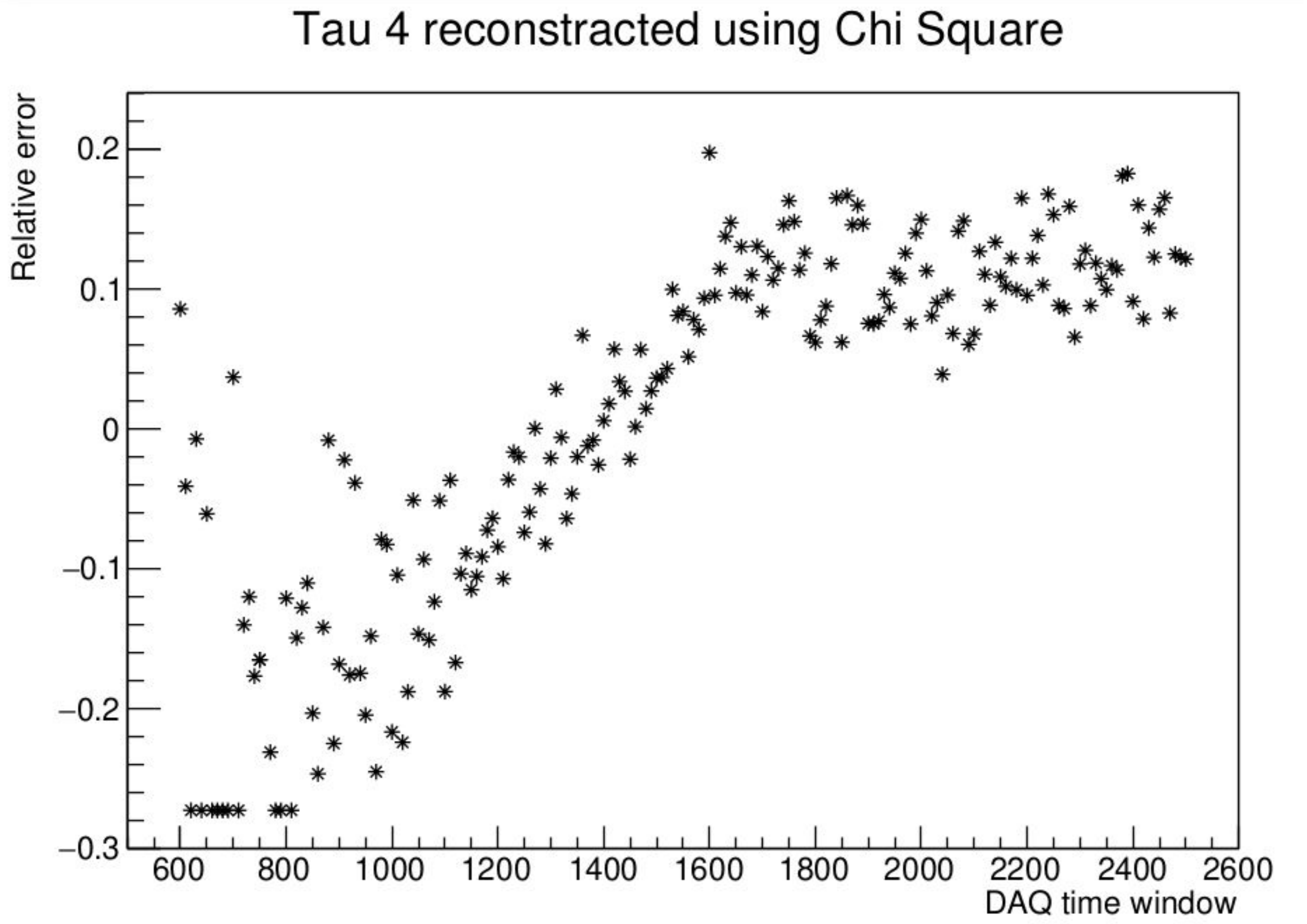
SHELDON AND SNiPER DECAY TIMES

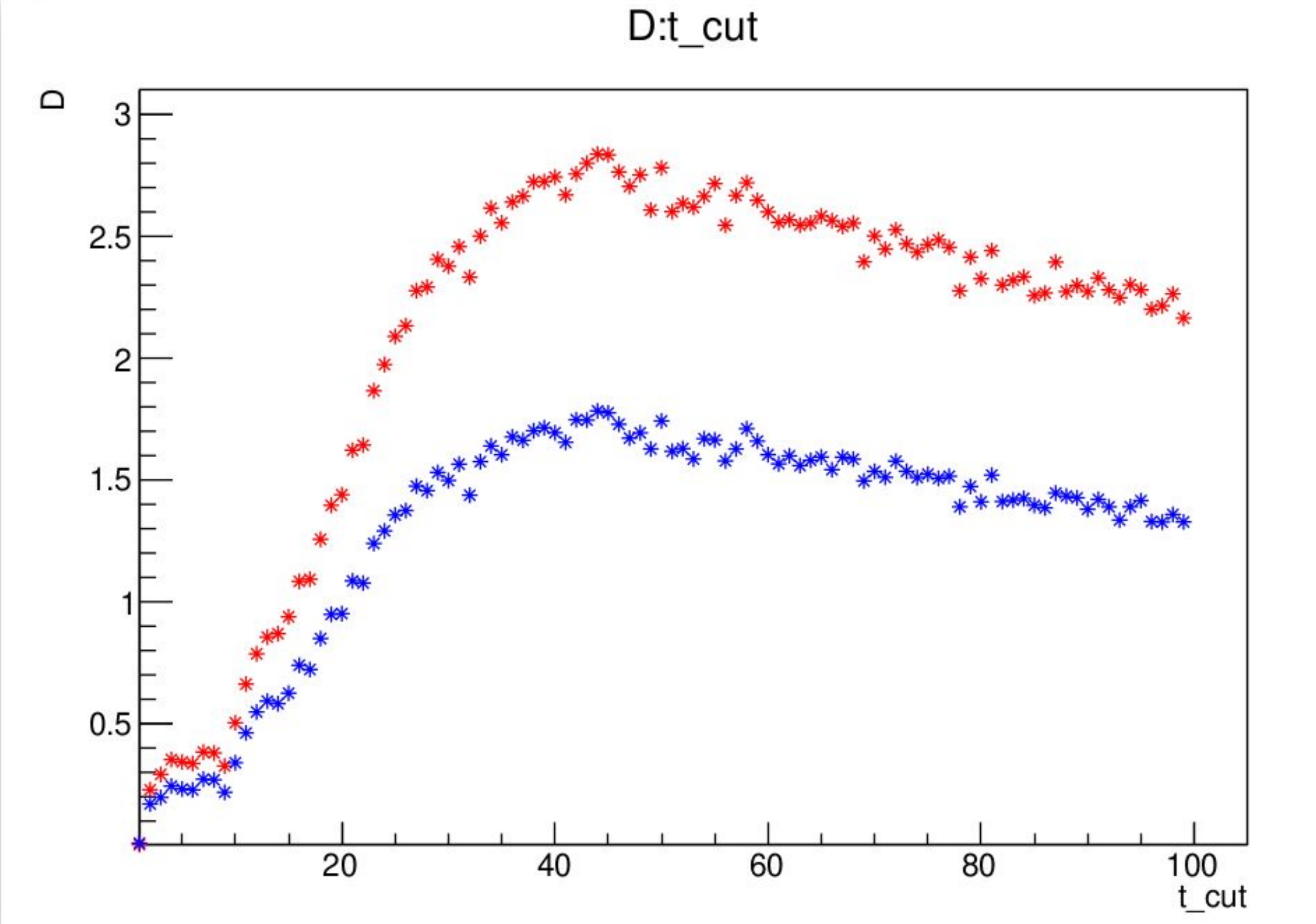






Tau4 relative error on DAQ time window
Relative error
0.1
0.05
0
-0.05
−0.1
1000
1500
2000
2500
3000
3500
DAQ time window (ns)


Tau 4 reconstracted using Chi Square
Relative error
0.2
0.1
0
−0.1
−0.2
−0.3
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
DAQ time window


D:t_cut
D
3
2.5
2
1.5
1
0.5
20
40
60
80
100
t_cut