



IN2P3
Les deux infinis



Towards a unified Low Energy software

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HK software meeting, 2020/05/28,

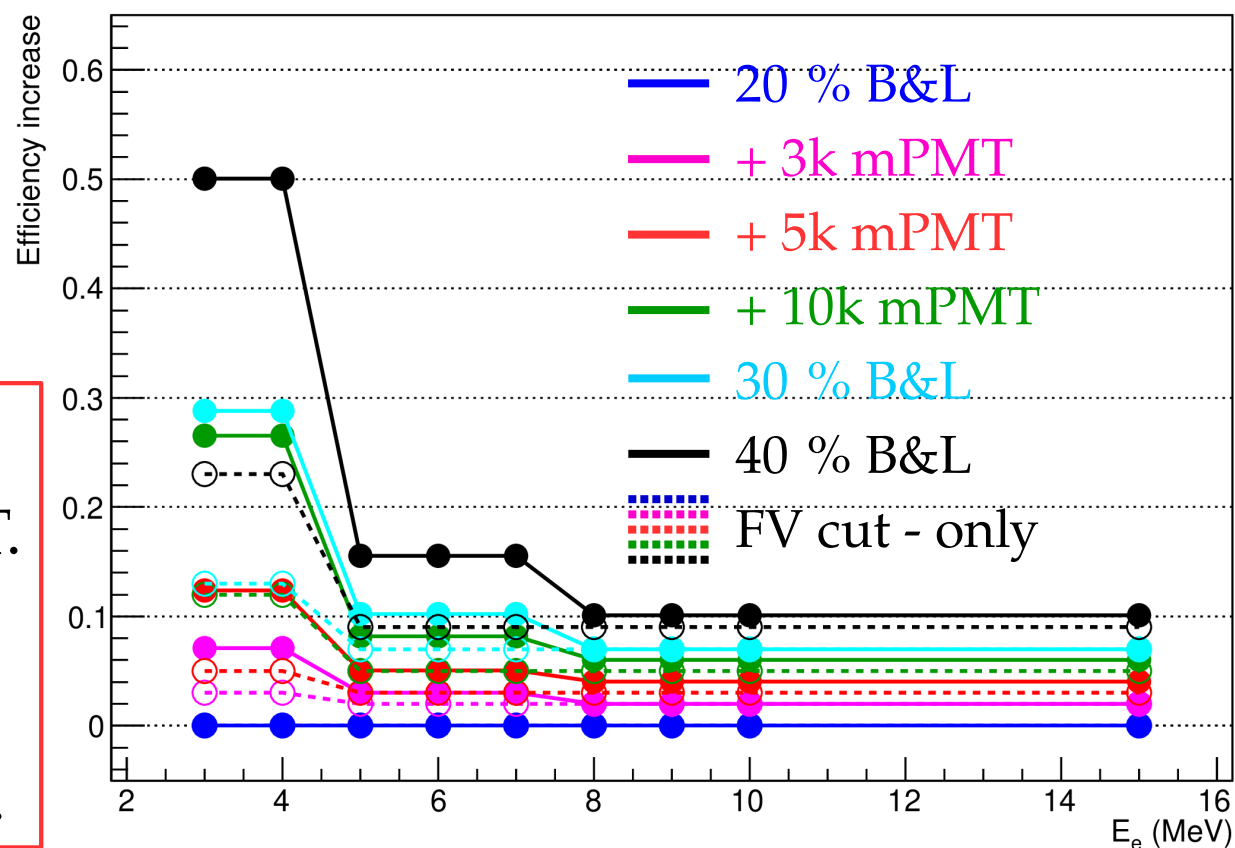
- Reconstruction side :
 - LEAF only has vertex reconstruction.
 - BONSAI is not perfectly tune for HK $\rightarrow$ Worse than LEAF.
- Analysis side :
 - We do not have a LE software for HK (example : Solar- ν selection).
 - We presented a 1st analysis using 2 solar cuts : FV and external background cut.

Upturn (< 5 MeV):

$\uparrow$ up to 27 % w/ + 10k mPMT.

Day-night (5 – 8 MeV):

$\uparrow$ up to 9 % w/ + 10k mPMT.

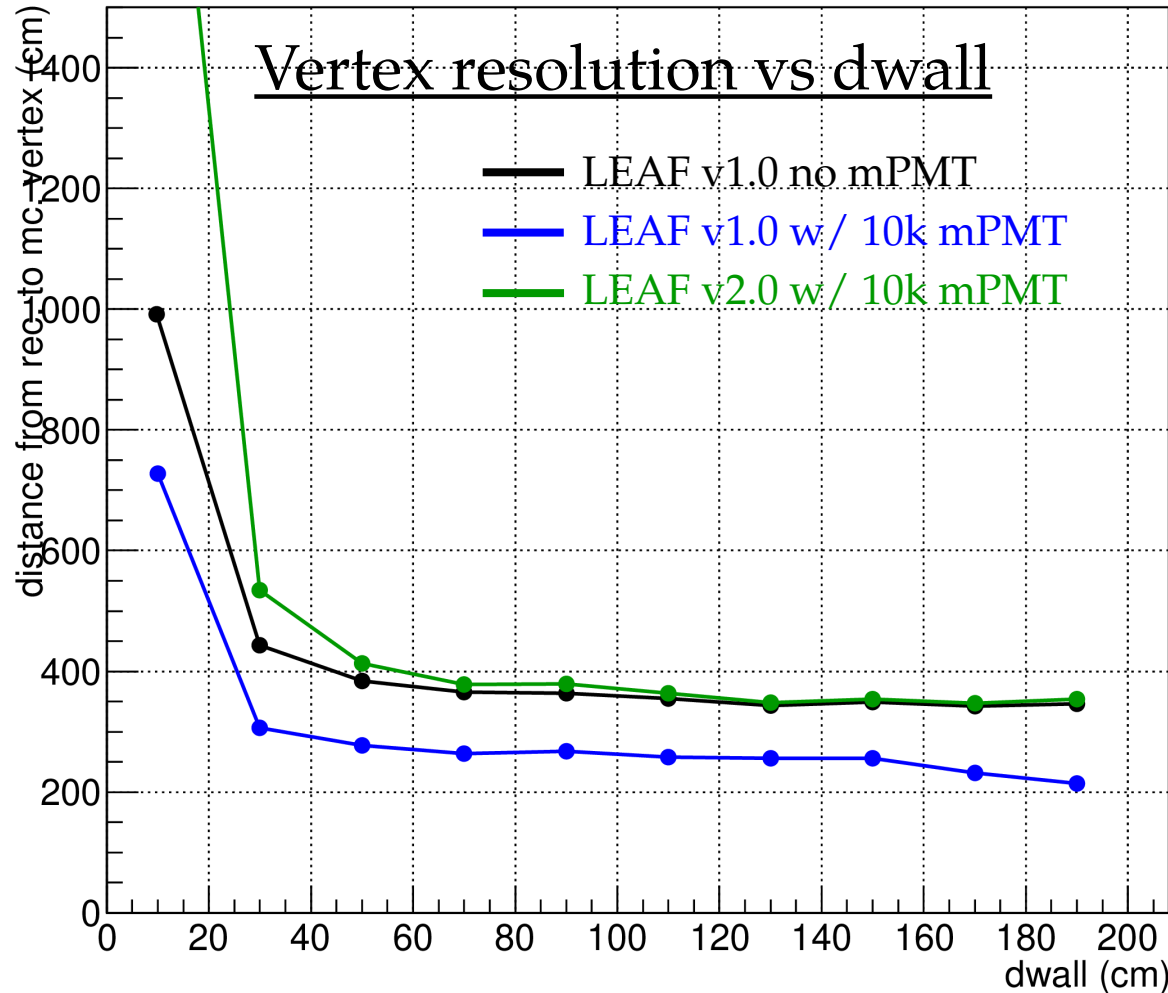


- Reconstruction side :
 - Upgrade LEAF to reconstruct the e direction and energy.
 - Upgrade LEAF to reconstruct other variables used for cuts : goodness of fit, dirKS etc.
- Analysis side :
 - Have a unified software to realize the Solar neutrino analysis.
 - Long-term : develop softwares for other LE analyses (SRN etc.).
- Other : other long-term goal → Have a proper background simulation

- Reconstruction side :
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- Today's presentation
- Analysis side :
 - Have a unified software to realize the Solar neutrino analysis.
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 - Other : other long-term goal → Have a proper background simulation

- Guillaume has already implemented into LEAF a reconstruction of :
event direction, goodness of fit and dirKS → Same formulae as BONSAI.
- Guillaume has also re-written LEAF to :
 - Clean the code → Using additional classes and methods.
 - Decrease the CPU-time for event processing.
- To use it : need to validate Guillaume implementation, and integrate it in a new release (let's call it v2.0).
- We will therefore first compare the following configurations:
 - 20 % B&L PMTs + 10k mPMT with mPMT masked.

- First test of the algorithm (50,000 3 MeV electrons):



- LEAF v2.0 using mPMTs does worse than v1.0 using B&L-only.
→ Large disagreement, especially at small dwall.

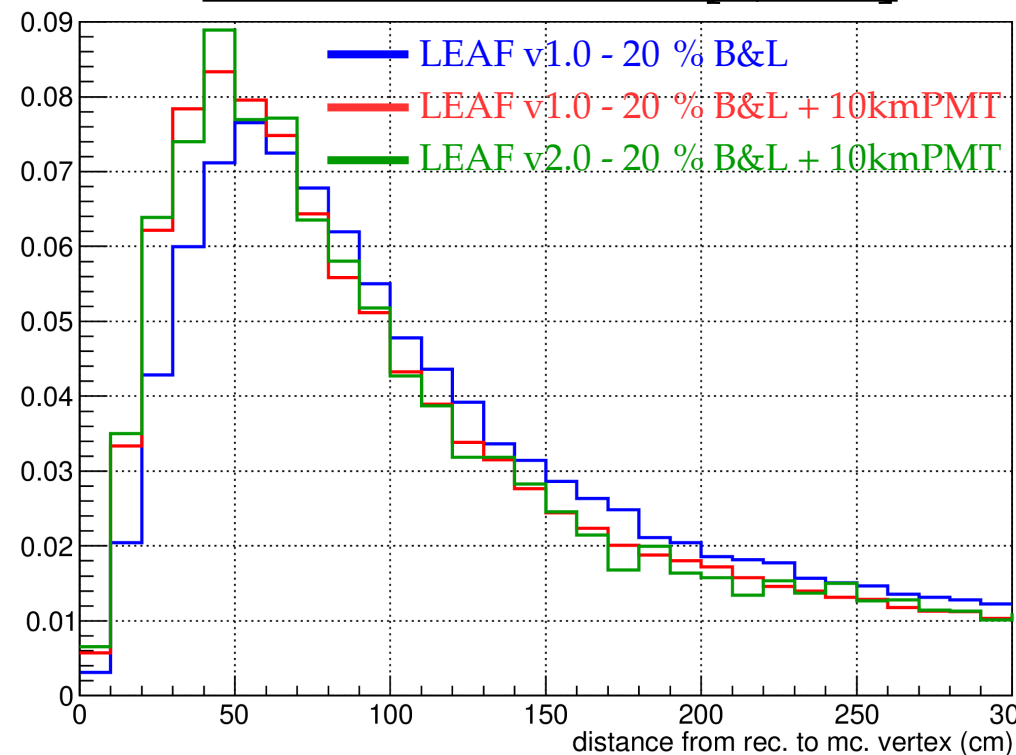
- Found a bug in the hit loop for hybrid PMT case (AnalyseEvent method)
→ Count 2 times the B&L hits if we use multi-PMTs → Solved !
- Moved/rename variables to make the change of parameter easier.
→ LEAF proceed first to a coarse grid search with pre-defined grid in the tank (and in time) → Keep the T (= tolerance) best candidate.
→ Then, 2 choices : do several more refined grid searches around the candidates, or a direct MINUIT minimization.

	Parameters
Coarse grid search	Step size = 300 cm, Tolerance = 60 Timing limits : -50ns → 50ns around trigger
Step by step or direct MINUIT	Direct MINUIT
Use PDF limits	Yes : -700 → + 1000 ns.
Use directionality	No

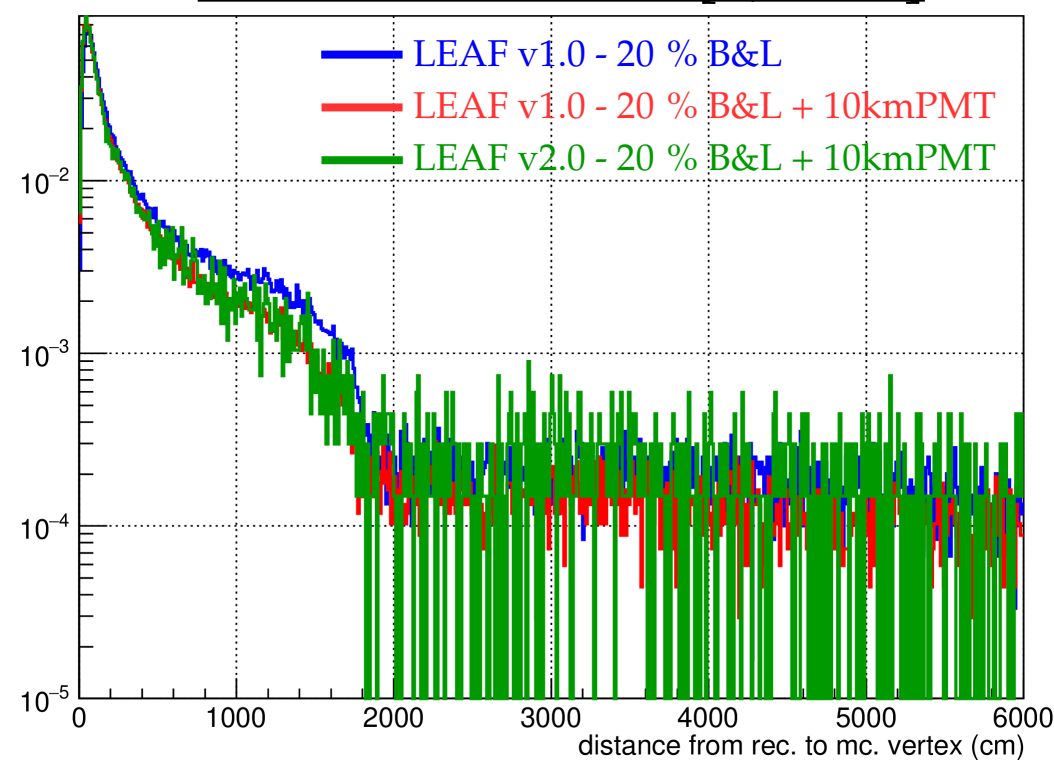
Validation of LEAF v2.0 – after bug fix ⁸

- Generated 50,000 3 MeV events close to the wall for both versions
 - Fitter as especially sensitive near tank wall : perfect for validation.
 - Compared 20k B&L + 10k mPMT versions.
 - After bug fix

Vertex resolution [0, 3m]



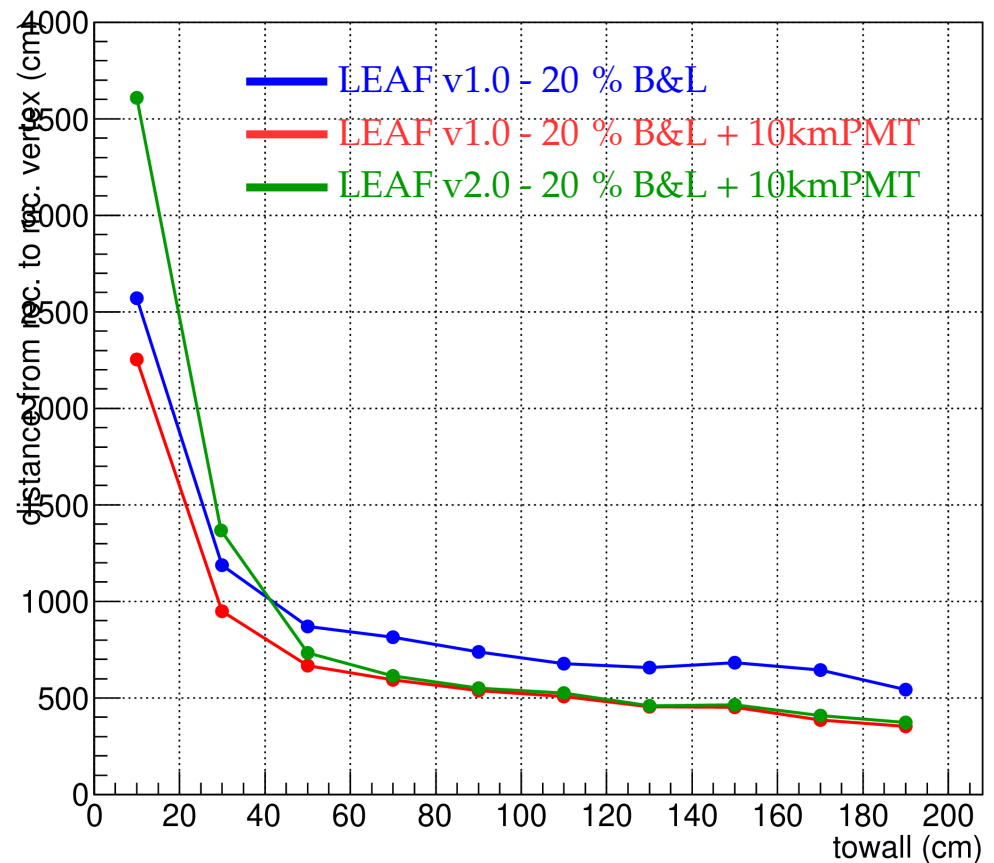
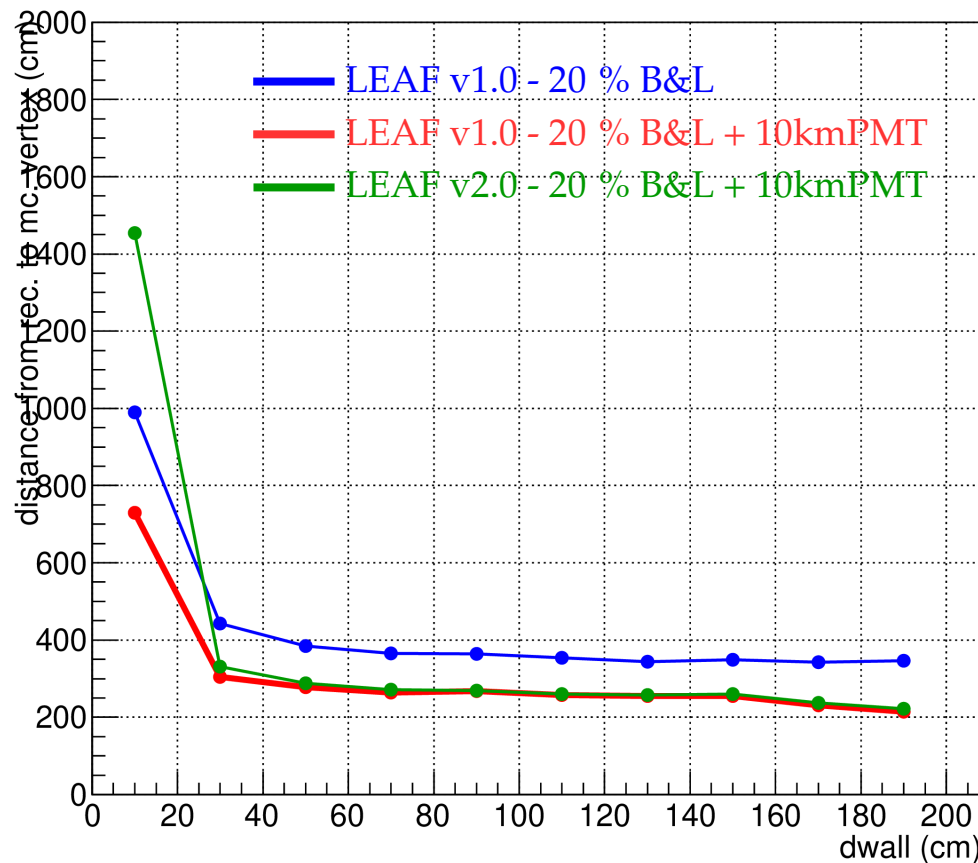
Vertex resolution [0, 60m]



- Almost perfect agreement between the two versions.

Validation of LEAF v2.0 – after bug fix ⁹

- Compared now as a function of dwall / towall :



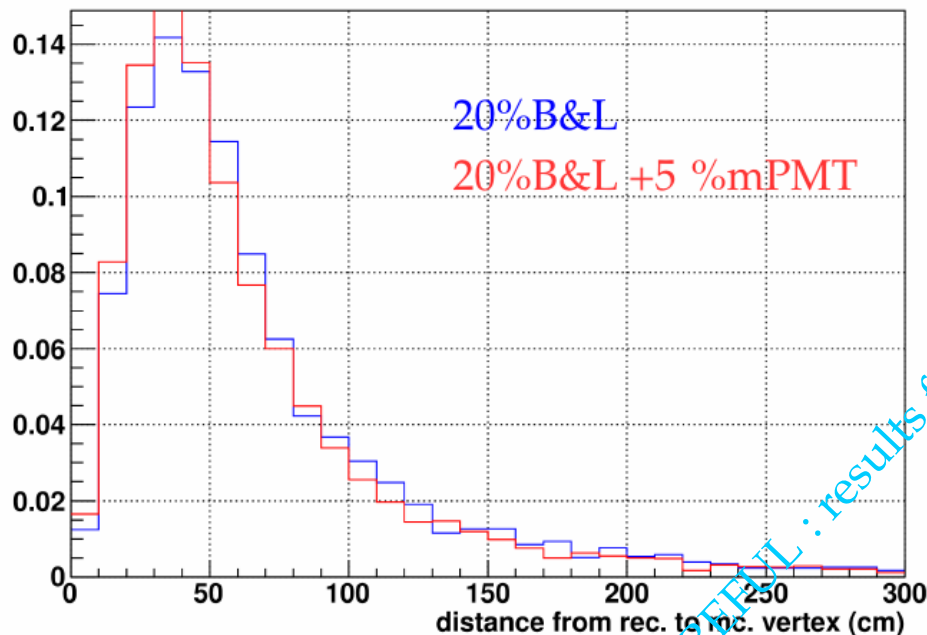
- Differences at very small dwall (< 30 cm) & towall (< 40 cm).
- Possible causes :
 - dark rate issue (should be indicated in the code), PDF differences...
 - To investigate

Reconstruction of the direction : BONSAI¹⁰

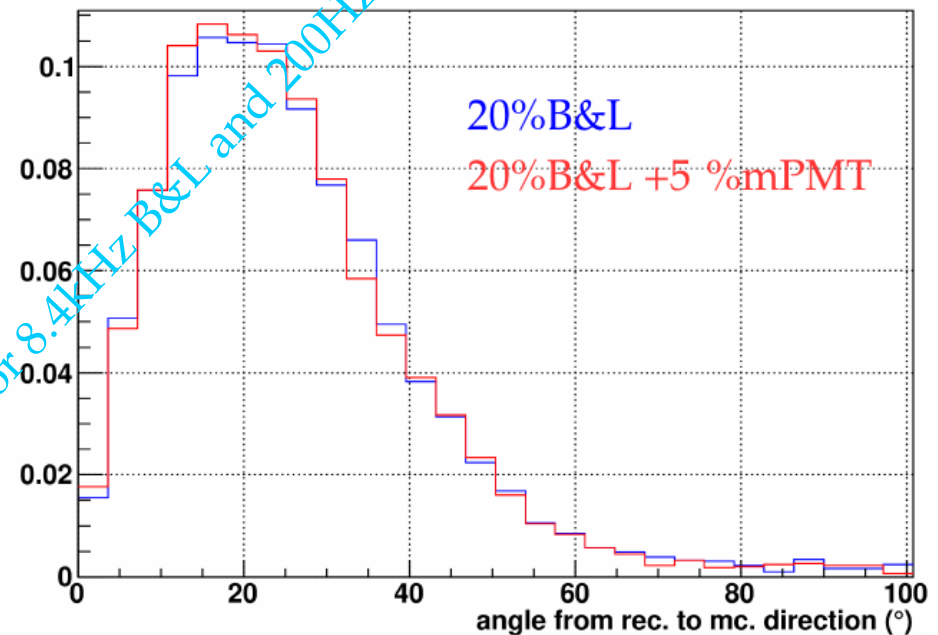
Reconstruction of direction : let's study its value for 10 MeV electrons uniformly located in the tank.

- BONSAI : average direction resolution is 33 degrees using 20k mPMT :

Vertex resolution



Direction resolution

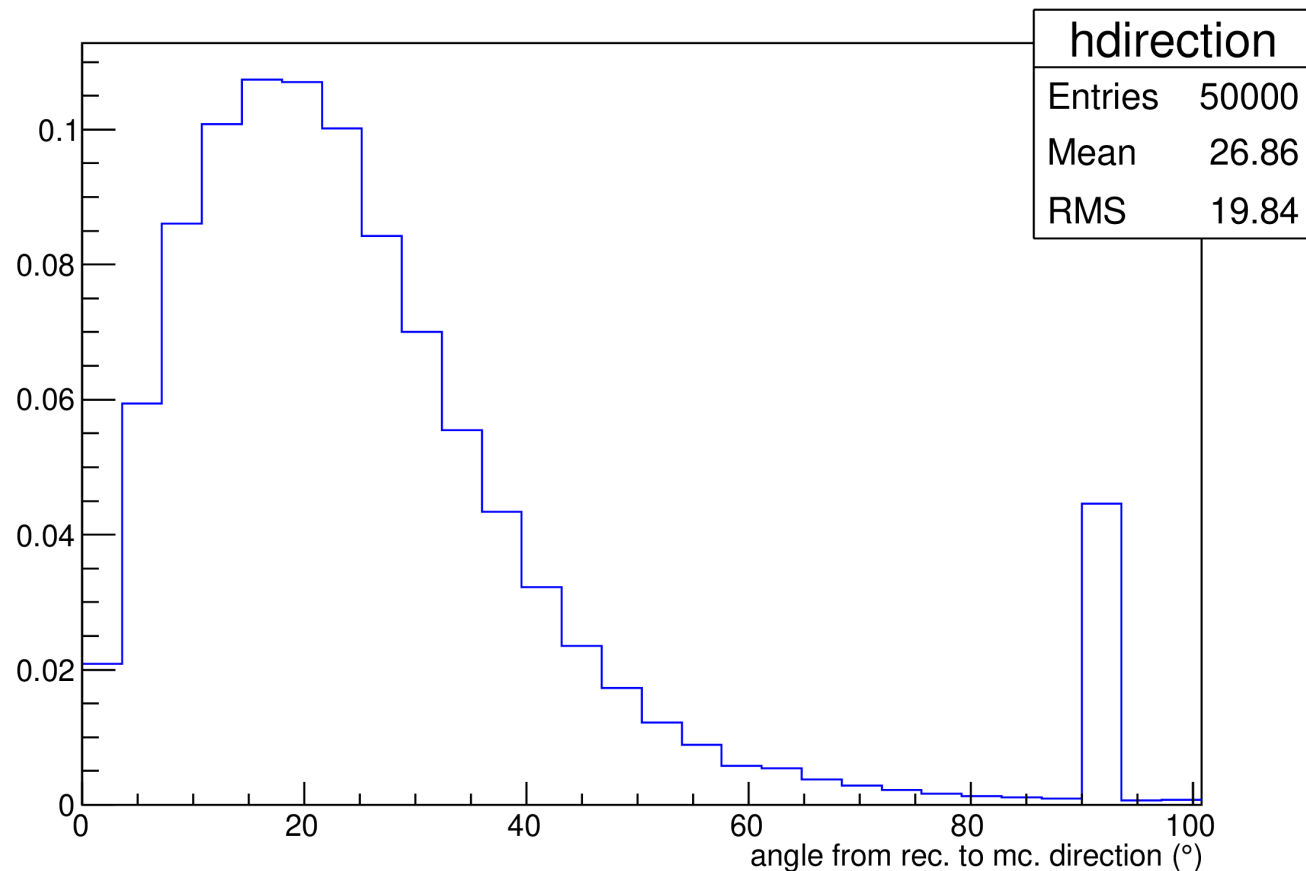


	Vertex resolution (cm)	Direction resolution (°)
20%B&L	77 cm	33.3°
20%B&L + 5 %mPMT	70 cm	31.5°

- Let's check this with LEAF now !

Reconstruction of the direction : LEAF ¹¹

- LEAF : 10 MeV electrons with 20k B&L + 10k mPMT.

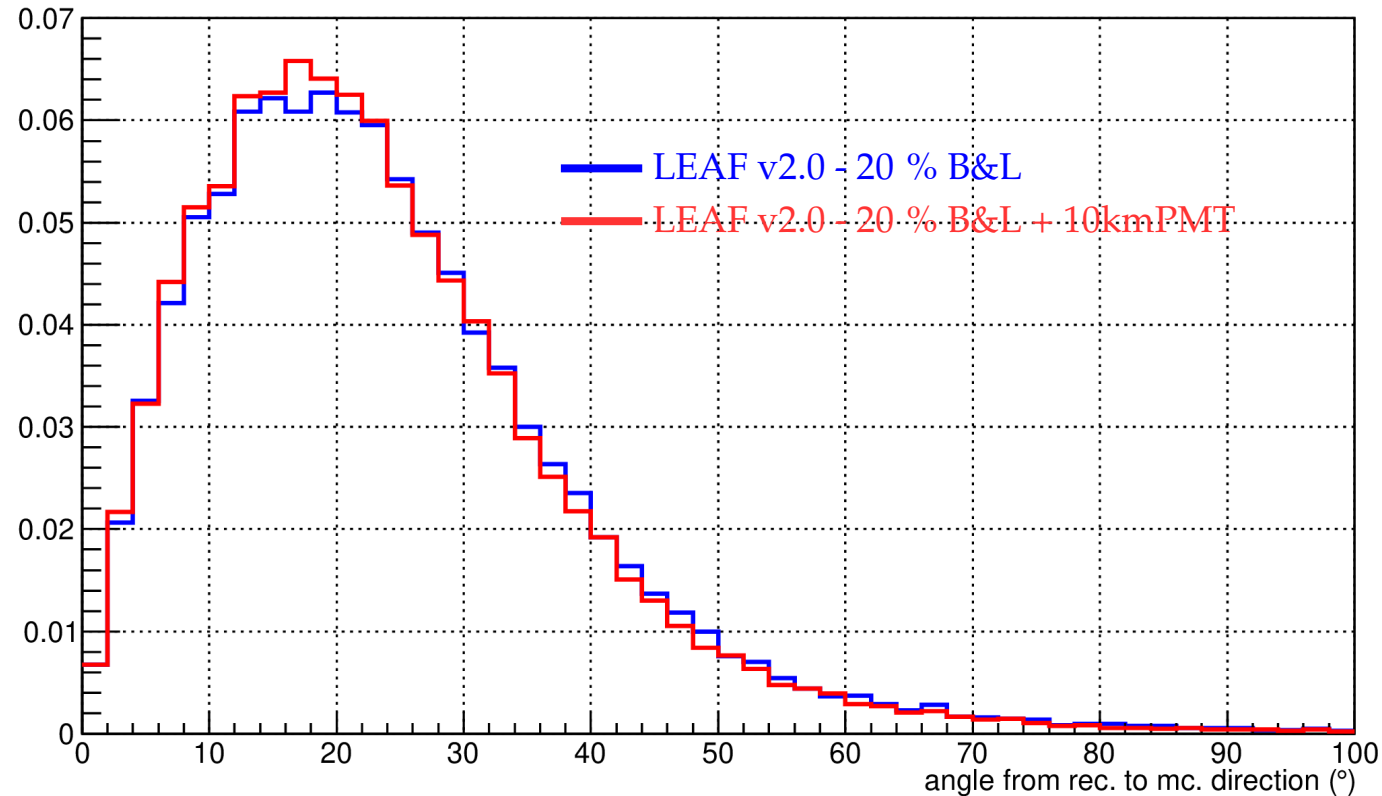


- Direction resolution (68 % CI) = 34.2 cm
- Spike at 90 degrees → Corresponds to cases where the reconstructed direction is not found (rec vector = (0,0,0))
→ I checked, this is cases where event is reconstructed out of HK.

Reconstruction of the direction : LEAF¹²

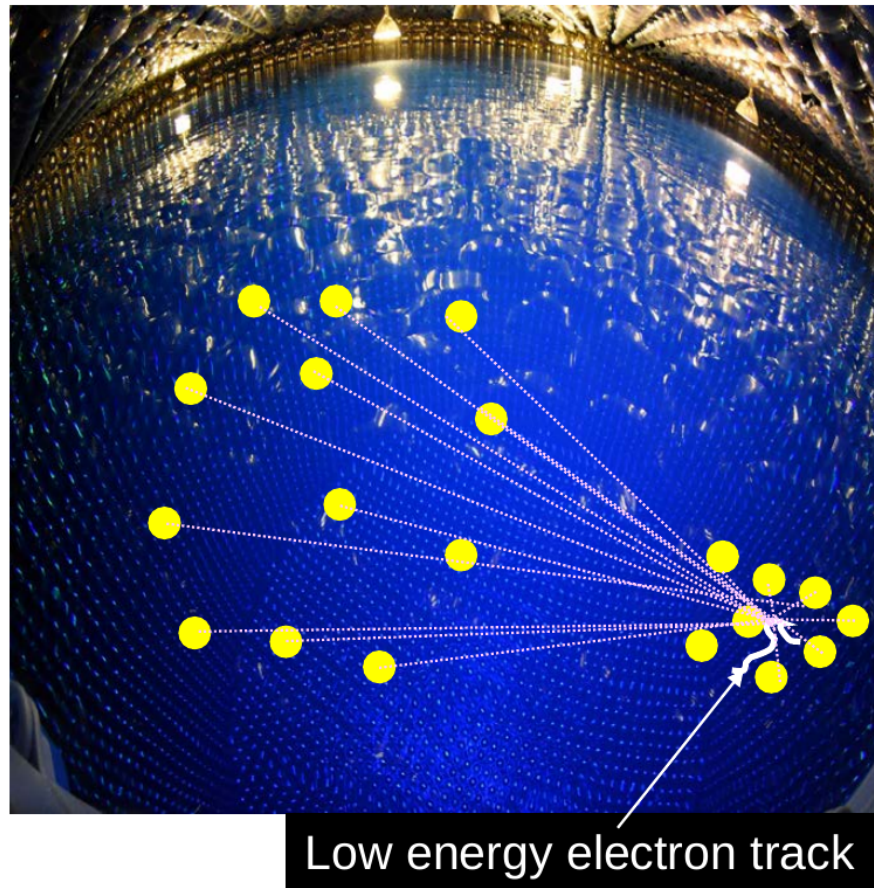
- LEAF : 10 MeV electrons with 20k B&L + 10k mPMT.

→ Using only events reconstructed in HK :



	Vertex resolution	Direction resolution
20 % B&L	62 cm	29°
20 % B&L + 10k mPMT	50 cm	28°

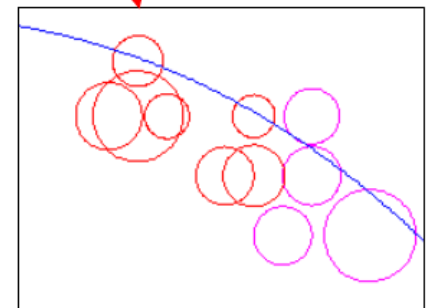
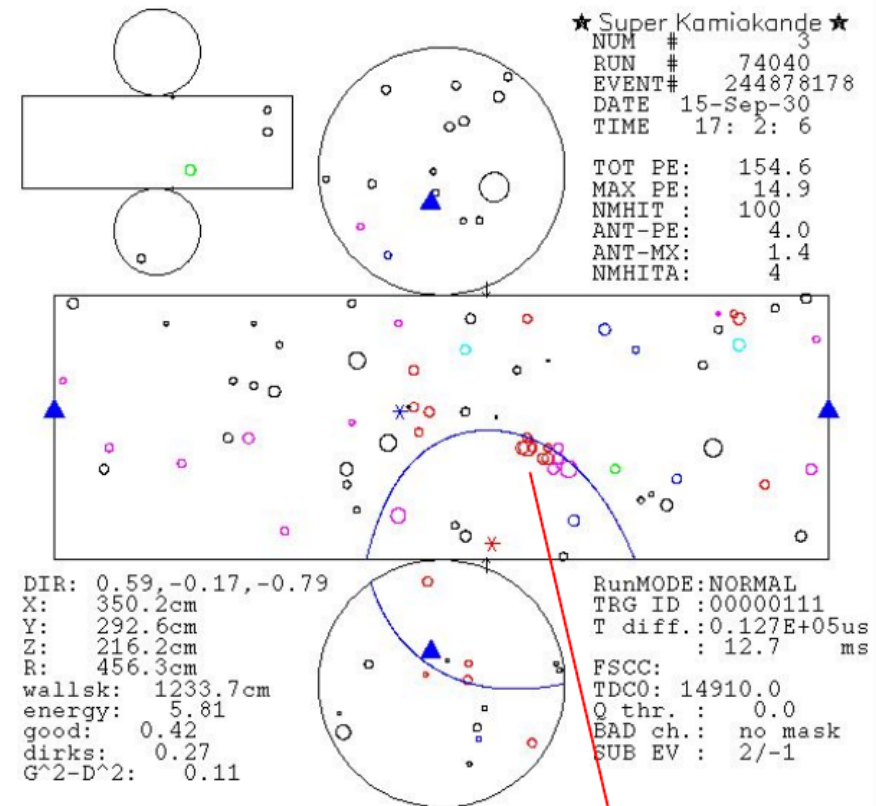
- Reminder : Nakahata-san talk for SK (2020/01/20 physics meeting) :



Because of the large multiple scattering, Cherenkov ring can hit nearby PMTs.

- dirKS : higher dirKS $\Leftrightarrow$ More uniform ring.

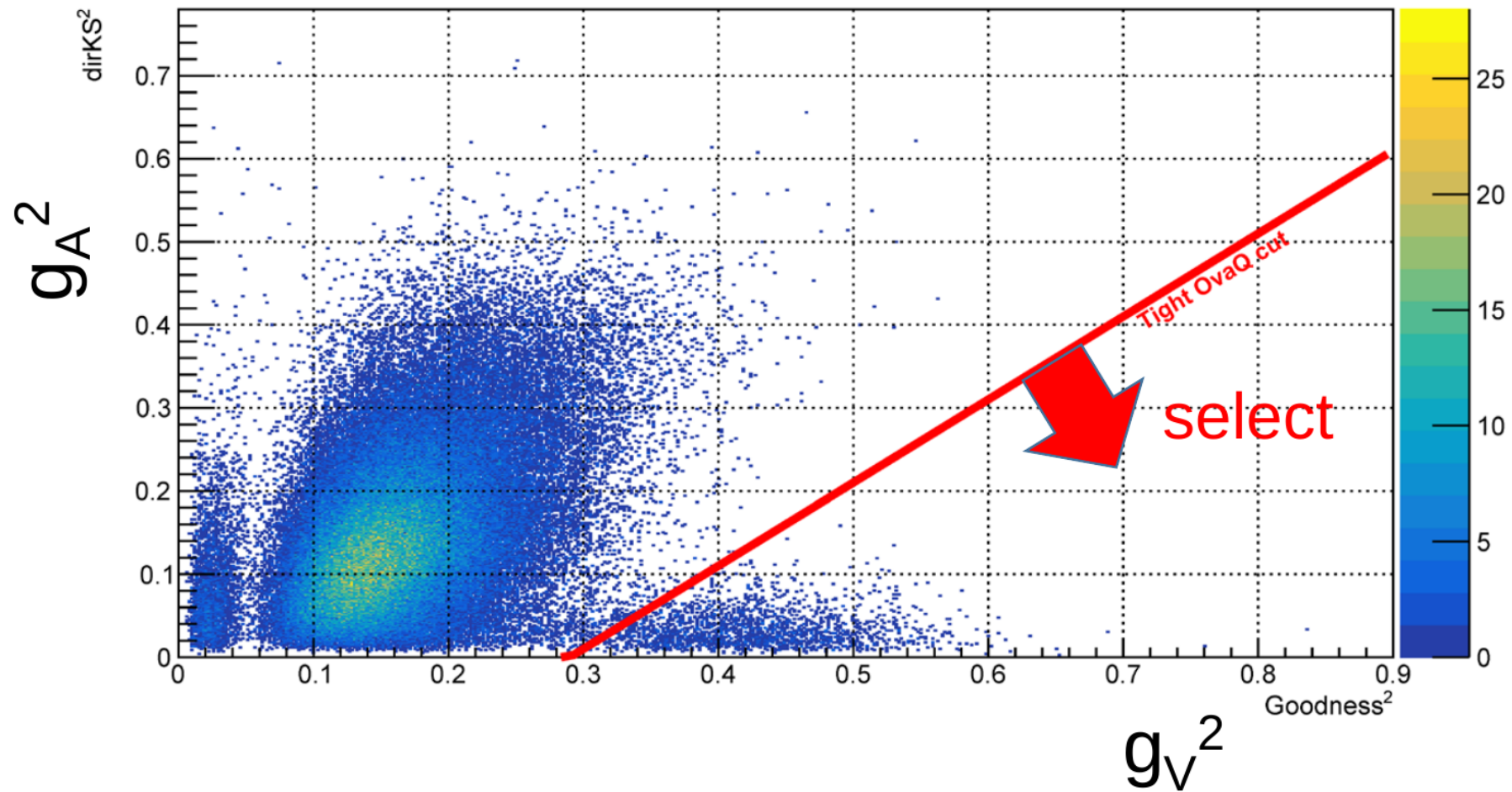
Data with $d_{\text{wall}} > 5\text{m}$ & $E_e > 5\text{ MeV}$



- Reminder : Nakahata-san talk for SK (2020/01/20 physics meeting) :

Dwall > 5m and E > 5MeV

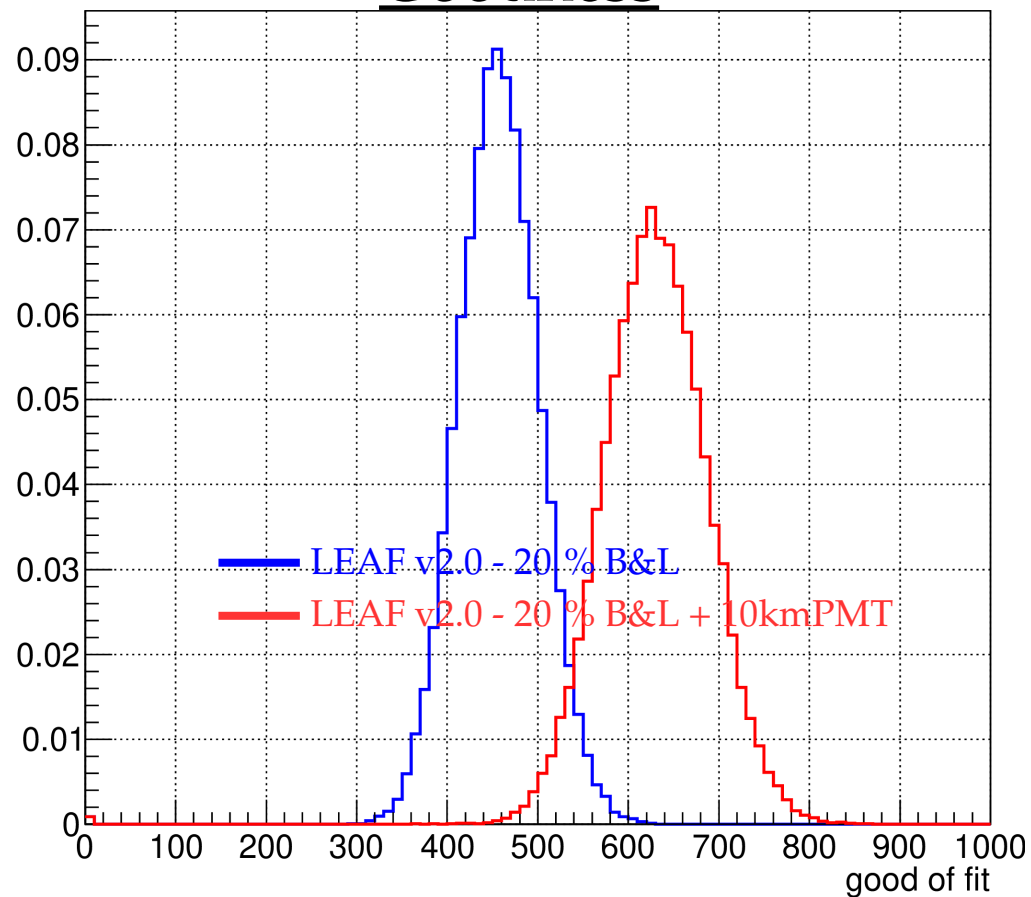
dirKS² vs Goodness² (E > 5 MeV, t_{diff} > 100 μs, d_{wall} > 5m)



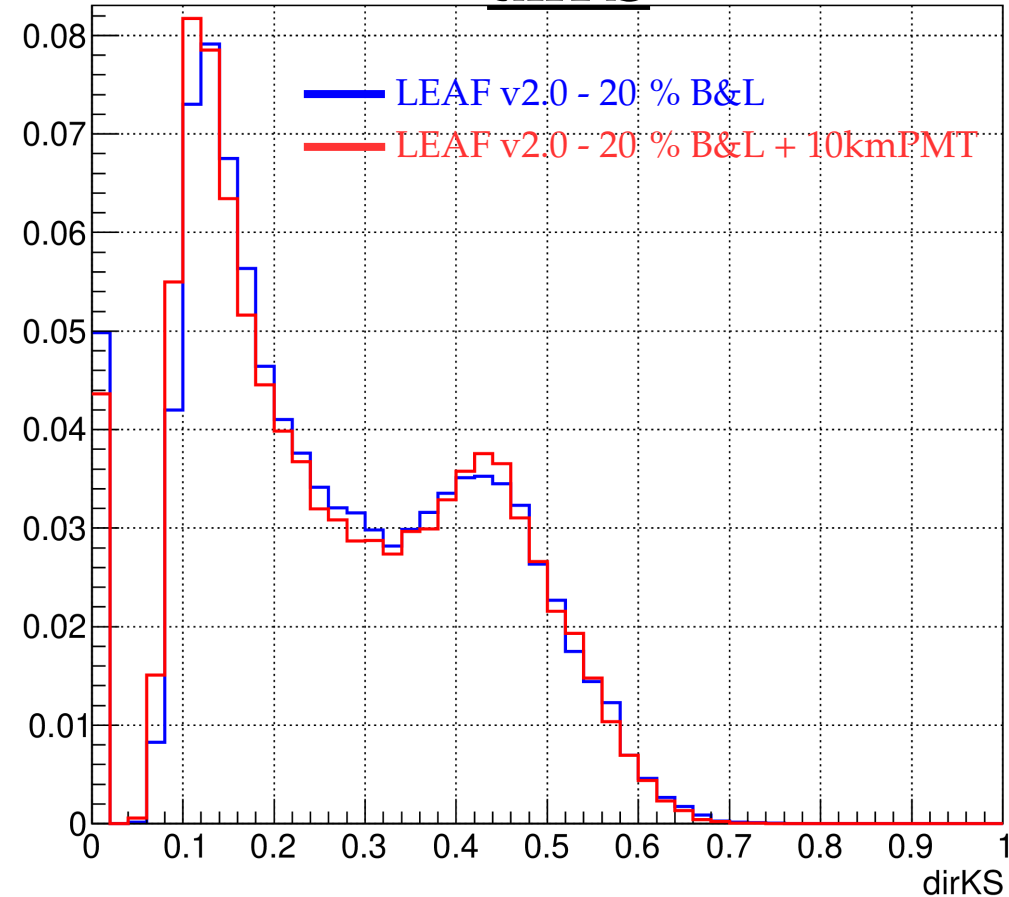
- Cut for large goodness of fit, but small dirKS (not-so-uniform ring).
→ OvaQ = goodness² - dirKS².

- LEAF : 10 MeV electrons with 20k B&L + 10k mPMT.

Goodness



dirKS



- Higher goodness of fit using mPMT → Ideal for the OvaQ cut.
→ But values of goodness very different than SK ! → To investigate.
- dirKS is not highly changed → I am surprised.
→ Overall OvaQ may be increased for signal w/ mPMT.

- Major message : LEAF is now able to reconstruct electron direction, as well as to provide a goodness of fit and dirKS
 - Excellent work by Guillaume.
 - Corrected major bug causing differences between LEAF v1.0 & v2.0
 - Agreement is almost perfect.
- Incoming work :
 - Investigate cause of $\neq$ between LEAF v1.0 and v2.0 at small dwall.
 - Investigate cause of $\neq$ in goodness of fit with SK results.
 - Dig deeper into the code to check if we can improve direction resolution, goodness of fit & dirKS better using mPMTs.
 - Compare BONSAI & LEAF direction of resolution for same DR.
 - Test the energy reconstruction implemented by Guillaume.

- BONSAI does not have any direction/energy reconstruction. It is done in another software in SK.
- Guillaume implemented a simplified version of the reconstruction of the direction.
- For energy reconstruction, it is done jointly with direction. There is a sequential fit of direction $\rightarrow$ energy $\rightarrow$ direction $\rightarrow$ energy ...
 - $\rightarrow$ We may move towards a joint energy/reconstruction fit.
 - $\rightarrow$ Guillaume has not tuned the energy reconstruction parameters (basically, relation between E_{true} and E_{vis} , as a function of d_{wall}).
 - $\rightarrow$ There is also another new algorithm called FLOWER for energy rec.
- Goodness of fit and dirKS are just placeholder $\rightarrow$ We should check.

- The first thing would be to understand the reconstruction of direction.
- Then, try to check out the energy reconstruction.