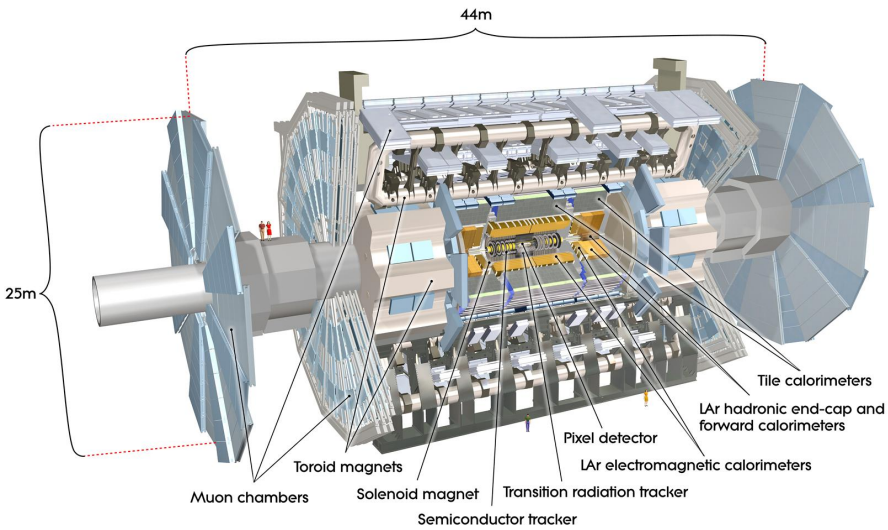
Neural Networks to mitigate Crosstalk in the Liquid Argon Calorimeter cells of the ATLAS Experiment.

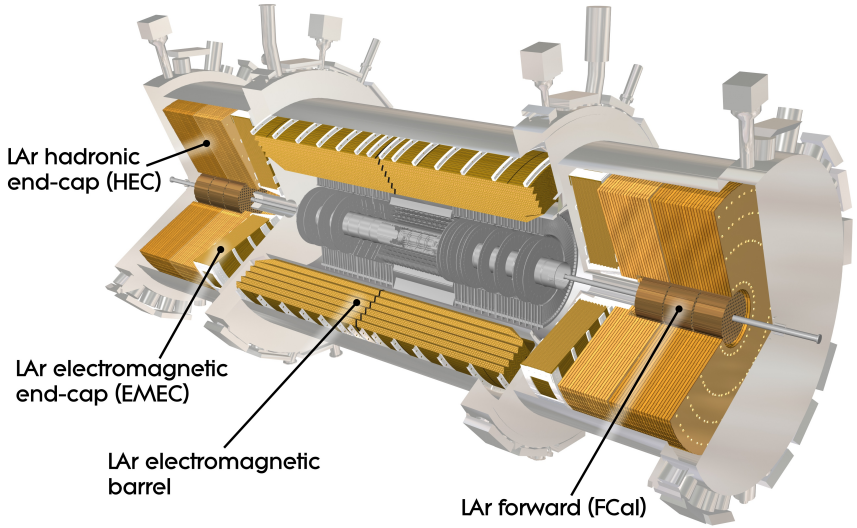
Marton Santos[1], Bertrand Laforge[2], Eduardo Simas[1], Paulo Farias[1], José Seixas[3].
[1]LSD – UFBA, [2]LPNHE – Sorbonne, [3]LPS – UFRJ.

ATLAS Collaboration Group

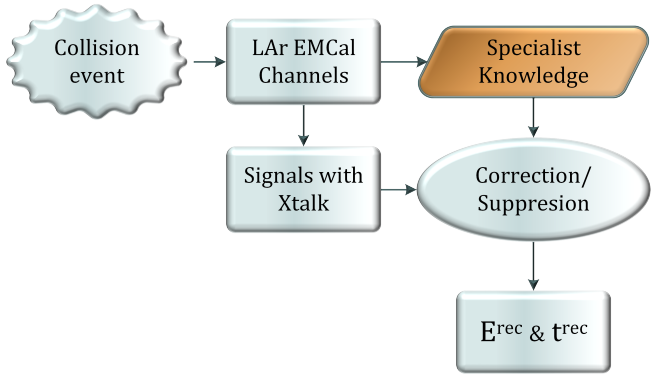
- Project: ASP-CALO Processamento Avançado de Sinais para Calorímetros de Altas Energias Finamente Segmentados. CAPES-COFECUB (04/2017):
- Researchers and institutions:
  - Dr. Bertrand Laforge – Sorbonne (LPNHE) – **France coord**.
  - Dr. David Calvet – Clermont Ferrand.
  - Dr. José M. Seixas – UFRJ (LPS) – **Brazil coord**.
  - Dr. Luiz P. Caloba – UFRJ.
  - Dr. Bernardo S. M. Peralva – UERJ.
  - Dr. Márcia Begalli – UERJ.
  - Dr. Eduardo F. Simas Filho – UFBA
  - Dr. Paulo C. M. A. Farias – UFBA.
  - Dr. Augusto S. Cerqueira - UFJF.
  - Dr. Rafael A. Nóbrega – UFJF.

- ATLAS - The biggest CERN experiment. Around 10^8 readout channels.
- It's a set of specialized experiments to tracking and measure particles that interact with mass;

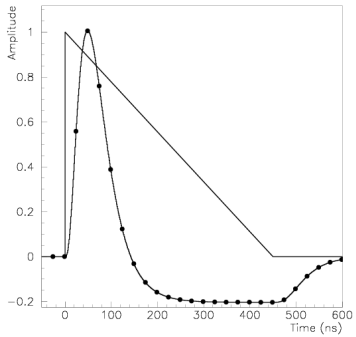


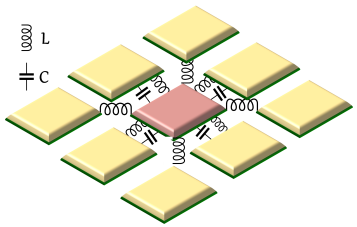


- The LAr calorimeters has close to 187.000 readout channels.
- High energy, mechanic structure, the readout electronic system, and the high cell channels density $\Rightarrow$ Crosstalk effect appears.



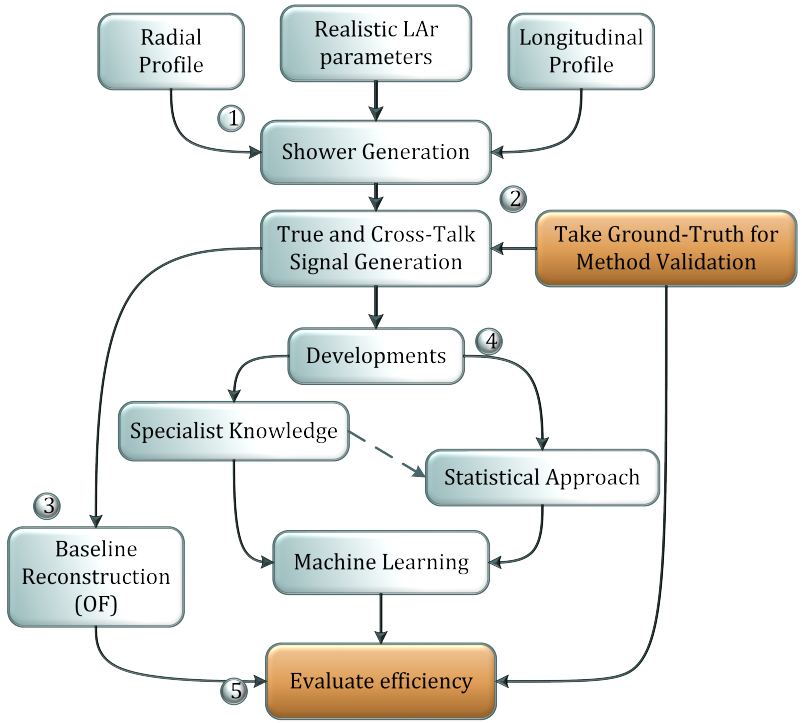
- XT insert a peak time-shifting and changing the amplitude of calibration signal of a cell;
- First-order XT coupling on the interest cell (RED) by the first neighborhood:



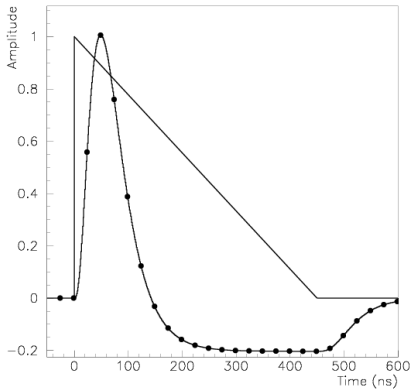


$$S_i^k = E^k g(t_i - \tau) + \sum_{j=2}^{9} E^j g_{XT}^{j \to k}(t_i - \tau) + b_i^k$$

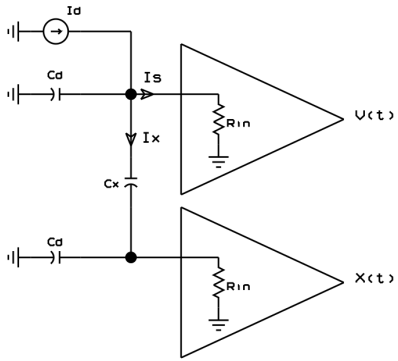
- S_i^k is the sample signal i on the k cell; $g(t_i - \tau)$: cell signal function; $g_{XT}^{j \to k}(t_i - \tau)$, the XT coupling function, and b_i: sample noise on the k cell.



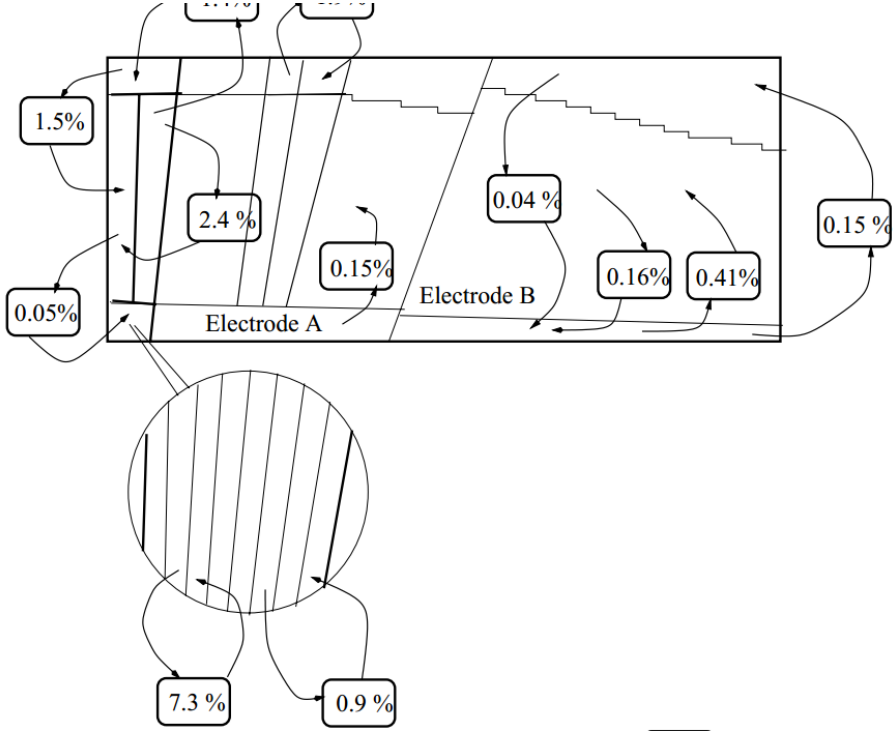
- **Goal**: Mitigate the XT influence on the ATLAS LAr calorimeter cells.



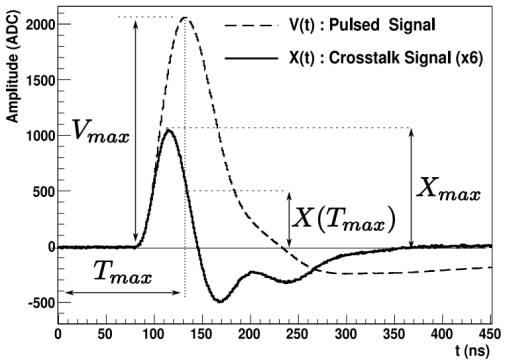
(a) Channel signal.



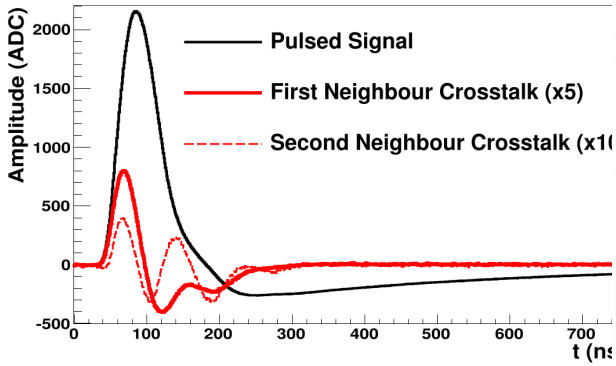
(b) Schematic coupling.



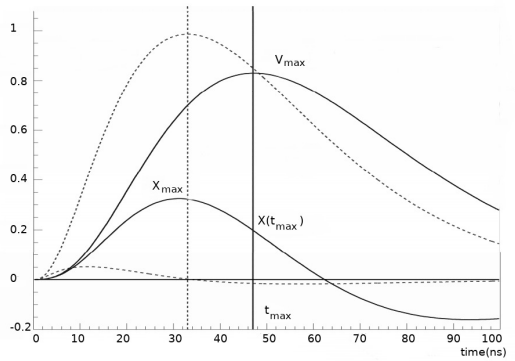
(c) XT on barrel



(d) XT definitions.

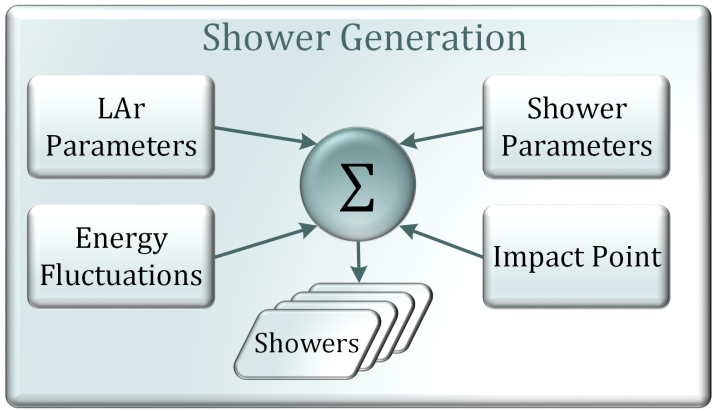


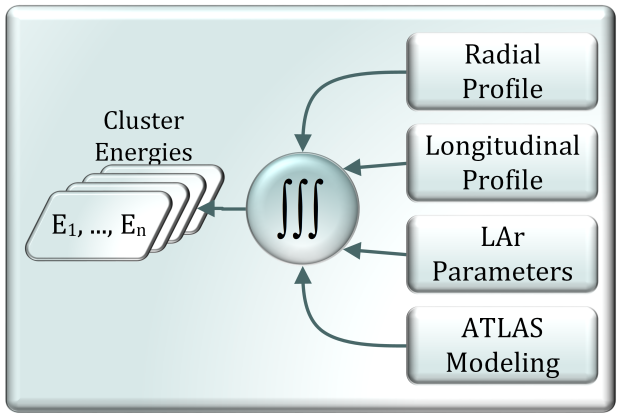
(e) XT typical shapes.



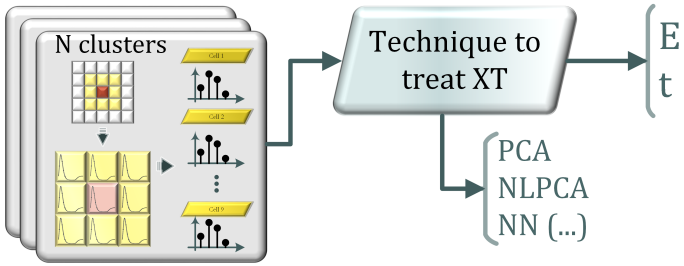
(f) XT signal consequences.

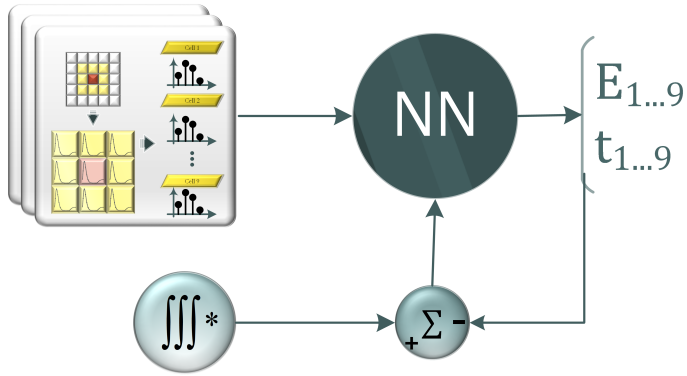
- Shower generation description blocks.



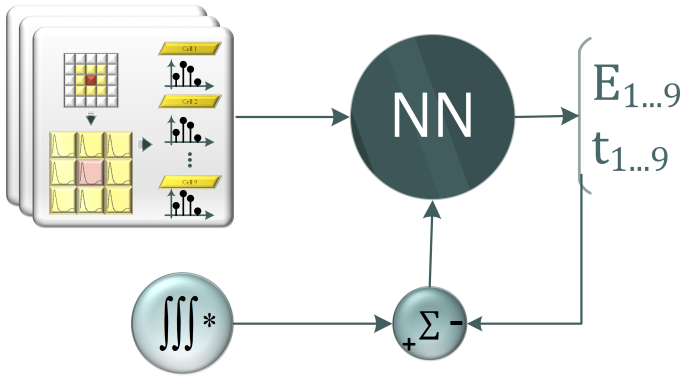


- Techniques under evaluation.





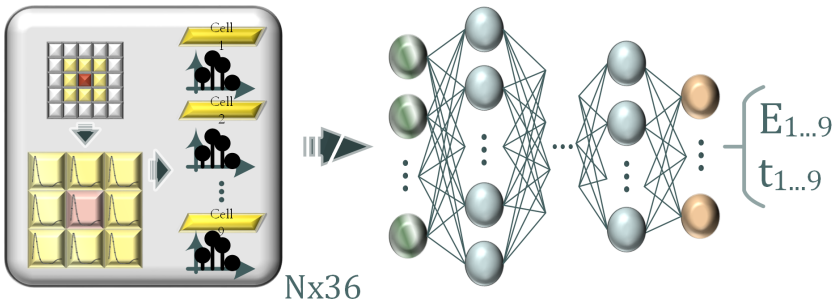
Setup for training



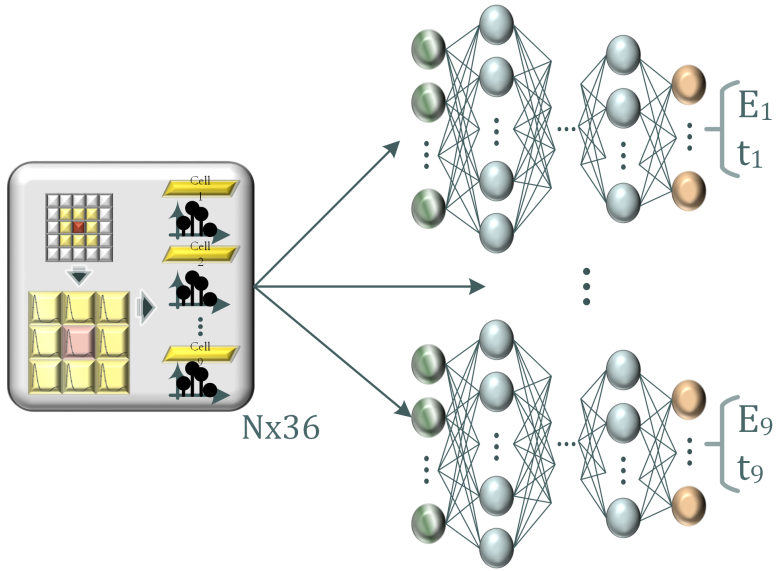
- Dataset: Input - $ENXT_{CL}$ — Target - $\int E$;
- Number of Samples: 745,000;
- Cross validation: Kfold; k=10. Training 9, Test 1;
- Number of Hidden Layerers: 1, 2, 3;
- N of Neurons: 36x[5, 10, 15, 20, 25]x9;
- Architecture: MLP Backpropagation FF;
- Optimizer: ADAM;
- Epochs: 5000;
- Metric: Accuracy;
- Stop criteria: mse;
- Activation: relu, sigmoid;
- Histograms: Output NN x $\int E$ x OF.

- Approaches under evaluation:

(a) No Specialist Approach.



(b) Specialist Approach.



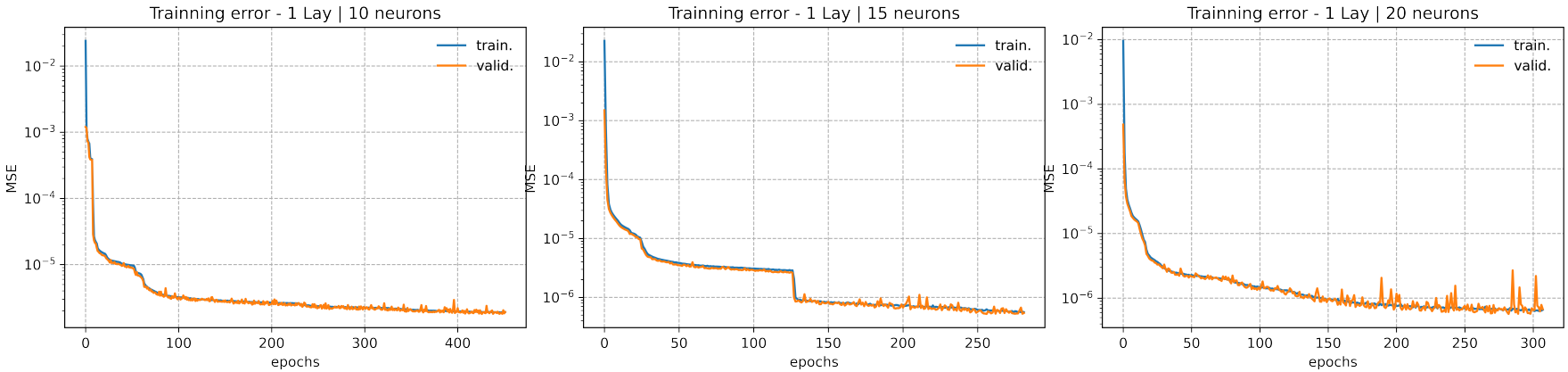
Averaged cluster energy [GeV]

ϕ \ η	-0.025	0	0.025	0.050	0.075
$\frac{\pi}{128}$	$0.377\ 10^{-3}$	$4.187\ 10^{-3}$	$10.010\ 10^{-3}$	$4.203\ 10^{-3}$	$0.382\ 10^{-3}$
0	$4.221\ 10^{-3}$	$356.900\ 10^{-3}$	1.268	$359.000\ 10^{-3}$	$4.522\ 10^{-3}$
$-\frac{\pi}{128}$	$10.040\ 10^{-3}$	1.267	37.910	1.297	$10.840\ 10^{-3}$
$\frac{2\pi}{128}$	$4.229\ 10^{-3}$	$359.900\ 10^{-3}$	1.299	$361.600\ 10^{-3}$	$4.563\ 10^{-3}$
$\frac{3\pi}{128}$	$0.386\ 10^{-3}$	$4.475\ 10^{-3}$	$10.760\ 10^{-3}$	$4.517\ 10^{-3}$	$0.397\ 10^{-3}$

- Summary of results using 1 hidden Layer.

	OF		[36 – 10 – 9] Neur.		[36 – 15 – 9] Neur.		[36 – 20 – 9] Neur.	
	Energy [GeV]	mse	Energy [GeV]	mse	Energy [GeV]	mse	Energy [GeV]	mse
Cell 1	0.378 ± 0.125	0.122	0.082 ± 0.081	0.001	0.091 ± 0.089	0.000	0.084 ± 0.083	0.000
Cell 2	1.959 ± 1.489	0.837	1.526 ± 1.479	0.005	1.507 ± 1.460	0.000	1.478 ± 1.430	0.002
Cell 3	0.387 ± 0.143	0.124	0.111 ± 0.110	0.001	0.102 ± 0.101	0.000	0.104 ± 0.102	0.000
Cell 4	1.922 ± 1.446	0.836	1.480 ± 1.427	0.005	1.486 ± 1.440	0.001	1.482 ± 1.435	0.001
Cell 5	38.743 ± 8.020	0.006	38.714 ± 8.039	0.000	38.735 ± 8.010	0.000	38.723 ± 8.037	0.000
Cell 6	2.009 ± 1.530	0.831	1.586 ± 1.530	0.006	1.608 ± 1.553	0.002	1.591 ± 1.540	0.002
Cell 7	0.384 ± 0.133	0.124	0.095 ± 0.093	0.000	0.092 ± 0.091	0.000	0.098 ± 0.097	0.000
Cell 8	2.112 ± 1.659	0.837	1.717 ± 1.670	0.002	1.704 ± 1.655	0.002	1.731 ± 1.680	0.002
Cell 9	0.397 ± 0.163	0.124	0.128 ± 0.127	0.000	0.101 ± 0.100	0.000	0.130 ± 0.128	0.000
	MSE	0.563	MSE	3.31E-03	MSE	9.23E-04	MSE	1.07E-03

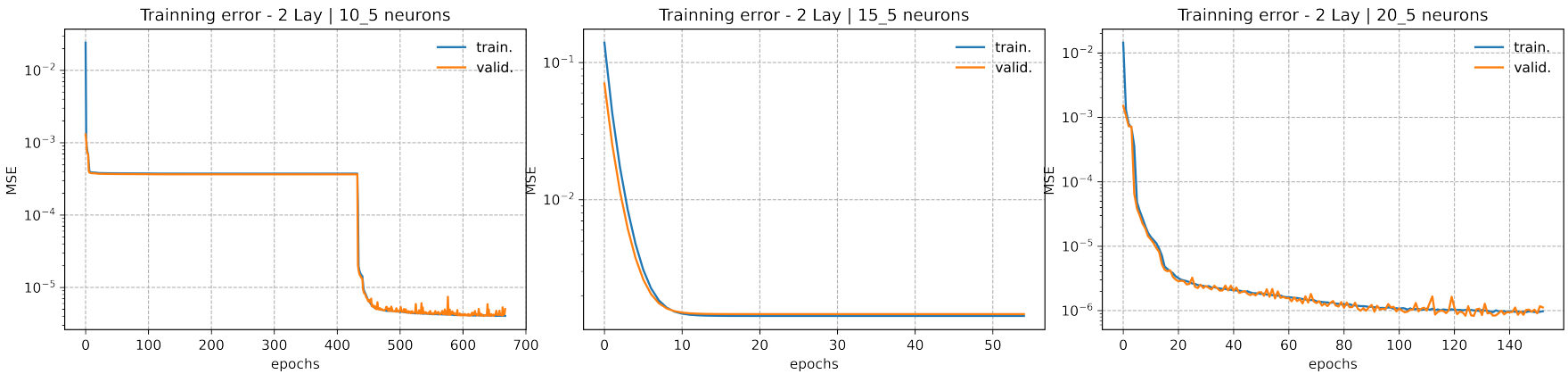
- Training Error in an arbitrary fold.



- Summary of results using 2 hidden Layers.

	OF		[36 – 10 – 5 – 9] Neur.		[36 – 15 – 5 – 9] Neur.		[36 – 20 – 5 – 9] Neur.	
	Energy [GeV]	mse	Energy [GeV]	mse	Energy [GeV]	mse	Energy [GeV]	mse
Cell 1	0.378 ± 0.125	0.122	0.091 ± 0.090	0.000	0.019 ± 0.004	0.009	0.087 ± 0.086	0.000
Cell 2	1.959 ± 1.489	0.837	1.510 ± 1.460	0.002	0.439 ± 0.091	2.260	1.457 ± 1.411	0.003
Cell 3	0.387 ± 0.143	0.124	0.096 ± 0.096	0.001	0.019 ± 0.004	0.012	0.107 ± 0.106	0.000
Cell 4	1.922 ± 1.446	0.836	1.450 ± 1.404	0.002	0.460 ± 0.095	2.156	1.470 ± 1.423	0.002
Cell 5	38.743 ± 8.020	0.006	38.722 ± 8.019	0.000	38.686 ± 8.022	0.000	38.780 ± 8.043	0.000
Cell 6	2.009 ± 1.530	0.831	1.654 ± 1.600	0.011	0.496 ± 0.103	2.366	1.566 ± 1.511	0.003
Cell 7	0.384 ± 0.133	0.124	0.091 ± 0.090	0.000	0.021 ± 0.004	0.009	0.102 ± 0.101	0.000
Cell 8	2.112 ± 1.659	0.837	1.692 ± 1.640	0.001	0.492 ± 0.102	2.707	1.749 ± 1.698	0.002
Cell 9	0.397 ± 0.163	0.124	0.000 ± 0.000	0.014	0.022 ± 0.005	0.014	0.110 ± 0.109	0.000
	MSE	0.563	MSE	5.80E-03	MSE	1.59	MSE	1.63E-03

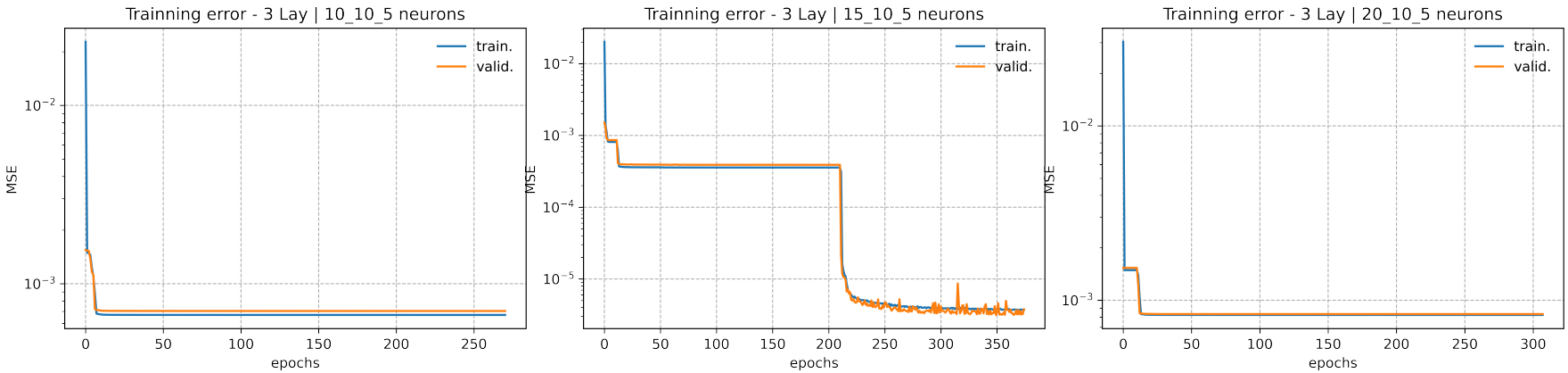
- Training Error in an arbitrary fold.



- Summary of results using 3 hidden Layers.

	OF		[36 – 10 – 10 – 5 – 9] Neur.		[36 – 15 – 10 – 5 – 9] Neur.		[36 – 20 – 10 – 5 – 9] Neur.	
	Energy [GeV]	mse	Energy [GeV]	mse	Energy [GeV]	mse	Energy [GeV]	mse
Cell 1	0.378 ± 0.125	0.122	0.000 ± 0.000	0.009	0.000 ± 0.000	0.008	0.080 ± 0.079	0.000
Cell 2	1.959 ± 1.489	0.837	0.000 ± 0.000	2.197	1.585 ± 1.534	0.003	1.446 ± 1.402	0.001
Cell 3	0.387 ± 0.143	0.124	0.000 ± 0.000	0.011	0.085 ± 0.084	0.000	0.000 ± 0.000	0.011
Cell 4	1.922 ± 1.446	0.836	0.020 ± 0.020	2.284	1.464 ± 1.415	0.003	1.489 ± 1.443	0.000
Cell 5	38.743 ± 8.020	0.006	38.730 ± 8.006	0.000	38.714 ± 8.077	0.000	38.655 ± 8.039	0.000
Cell 6	2.009 ± 1.530	0.831	1.539 ± 1.489	0.001	1.597 ± 1.543	0.002	0.000 ± 0.000	2.522
Cell 7	0.384 ± 0.133	0.124	0.020 ± 0.020	0.010	0.032 ± 0.032	0.008	0.000 ± 0.000	0.009
Cell 8	2.112 ± 1.659	0.837	1.642 ± 1.594	0.001	1.672 ± 1.624	0.006	0.000 ± 0.000	3.060
Cell 9	0.397 ± 0.163	0.124	0.108 ± 0.107	0.000	0.128 ± 0.127	0.000	0.000 ± 0.000	0.014
	MSE	0.563	MSE	1.06	MSE	4.79E-03	MSE	1.32

- Training Error in an arbitrary fold.



- The MLP structure achieve good results to reconstruct the energy value for the hottest cell with low MSE take into account the standard method, Optimal Filter (OF);
- At lower energies reconstruction process produces a large fluctuation. On the OF and using NN.
- Evaluate the specialist approach to reconstruct energies to compare the best approach to XT mitigation;
- Investigate an adequate Recurrent NN structure sensitive to time information on input data to reconstruct Energy;
- Continues with the ATLAS validation process: Using Monte Carlo data to validate EMshower + ML approach, and use collision data as the last validation step.

Thanks for your attention!

The authors thank the financial support from FAPESB, FAPERJ, RENAFAE, CNPq, and CAPES. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001