

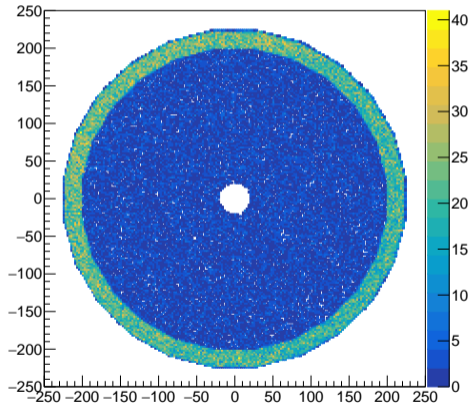
# Beam direction shifting in **ECAL+STT**

Artem Chukanov, Bing Guo, Roberto Petti

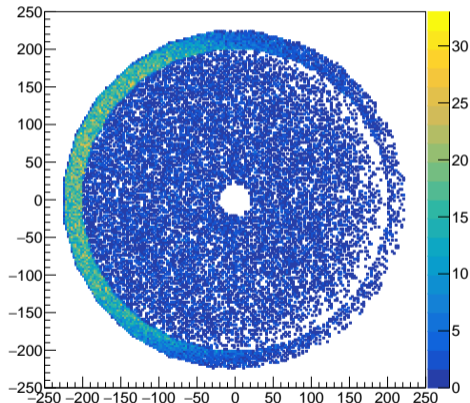
SAND meeting 12<sup>th</sup> of May 2020

## Vertices distribution - ECAL events

true events  
vertex distribution



reconstructed events  
vertex distribution



## ECAL efficiency

Efficiencies for ECAL+3DST configuration

Overall efficiency (whole ECAL)	23%	
With $ x  < 150$ cm	20%	Use this rate here
Upstream half + With $ x  < 150$ cm	19%	
Downstream half + With $ x  < 150$ cm	< 1%	
With $ x  < 100$ cm	14%	
3DST interaction (10 ton FV)	> 90%	

FV in beam direction frame for ECAL+STT configuration:  $z < 0$ ,  $|x| < 169$  cm

	total	FV	FV efficiency	$ x  < 150$ cm
true	153371	43710	28.5%	–
rec	51361	29639	57.7%	–
rec efficiency	33.5%	67.8%	19.3%	17.6%

Our number is based on STT which has uniform acceptance, while in case of 3DST some part of the volume is empty

## Shifting beam direction

We made a beam shift along X axis with the step 12.5 cm and measured  $\chi^2$  for re-weighted spectra and events number as we did for other beam variations.

Used 80 bins for energy interval [0; 20] GeV

Used 34 bins for X axis in the range [-170; 170] cm for ECAL events

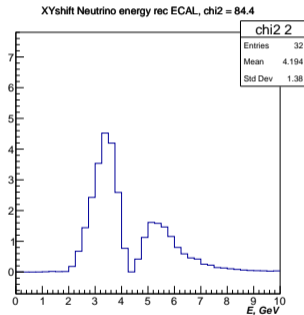
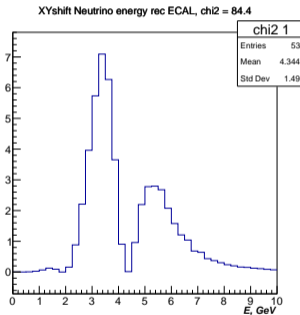
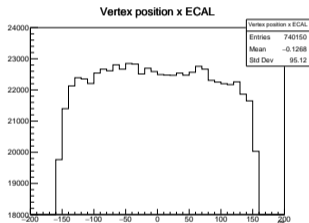
Used 32 bins for X axis in the range [-160; 160] cm for STT events

We use one week exposure with  $3.78 \times 10^{19}$  p.o.t.

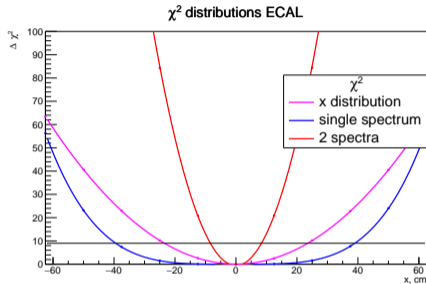
# ECAL events

## Chi-square distribution

### vertex distribution



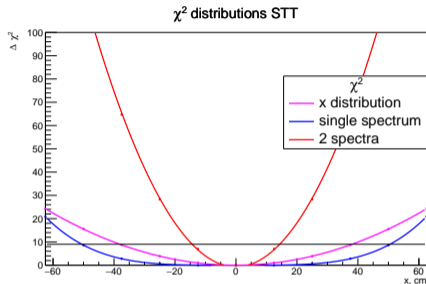
## Beam shift for ECAL events



Coordinate resolution ( $\Delta\chi^2 = 9$ ):

- spectra comparison (single spectrum) – 39.4 cm
- spectra comparison (2 spectra) – 8.4 cm
- events number comparison – 23.5 cm

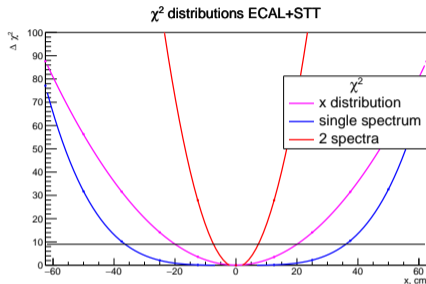
## Beam shift for STT events



Coordinate resolution ( $\Delta\chi^2 = 9$ ):

- spectra comparison (single spectrum) – 50.6 cm
- spectra comparison (2 spectra) – 14.4 cm
- events number comparison – 38.0 cm

## Beam shift for ECAL+STT events



Coordinate resolution ( $\Delta\chi^2 = 9$ ):

- spectra comparison (single spectrum) – 36.4 cm
- spectra comparison (2 spectra) – 7.4 cm
- events number comparison – 19.9 cm



## Results

Values of shifts with significance  $\Delta\chi^2 = 9$  in one week

Detector element	X distribution	$E_\nu$ distribution	
		Single spectrum	2 spectra ( $x < 0, x > 0$ )
ECAL	23.5 cm	39.4 cm	8.4 cm
LAr+STT	38.0 cm	50.6 cm	14.4 cm
combined	<b>19.9 cm</b>	36.4 cm	<b>7.4 cm</b>

ECAL+STT achieves a significance  $> 3$  in one week for variations of the beam direction of 0.13 mrad

## Summary

- need to check differences in acceptance between ECAL+STT and ECAL+3DST configurations
- performed detailed study of the sensitivity of the ECAL+STT configuration to changes of the beam direction
- marginal sensitivity to changes of the beam direction found using directly the primary vertex distributions, regardless of the number of bins considered
- good sensitivity ( $\Delta\chi^2 \geq 9$ ) to changes of the beam direction with ECAL+STT using separate spectra of reconstructed neutrino energy for  $X(Y) < 0$  and  $X(Y) > 0$ : 7.4 cm in one week ( $3.78 \times 10^{19}$  pot)
- ECAL+STT is sensitive to changes in beam direction of 0.13 mrad in one week, to be compared with an average beam divergence of 1.5 mrad