LUND UNIVERSITY

Status of the detector design studies for ESSνSB

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EuroNuNet

cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

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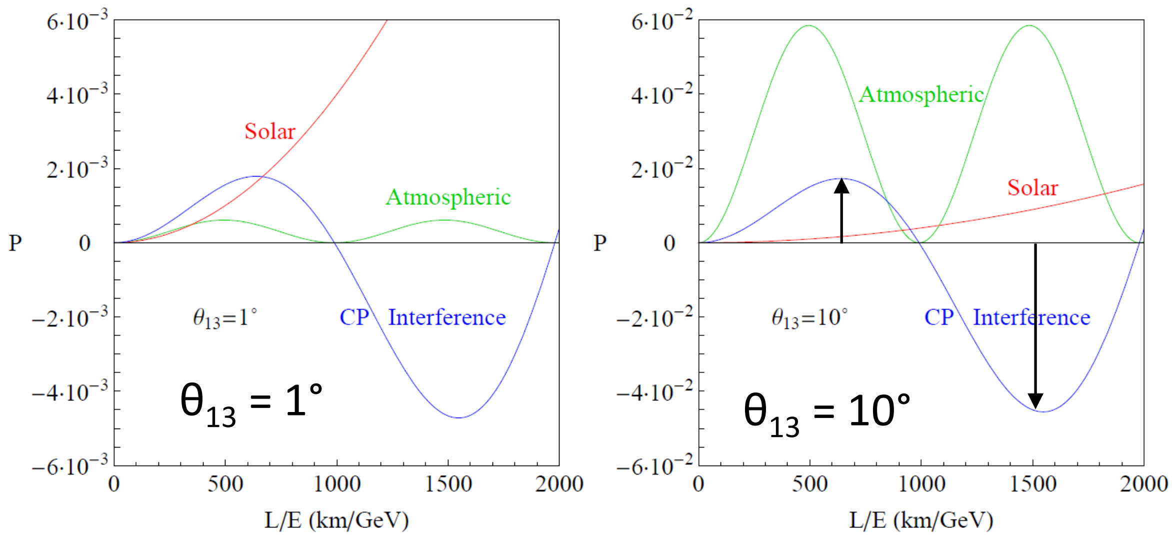
Introduction

"Discovery and measurement of leptonic CP violation using an intensive neutrino Super Beam generated with the exceptionally powerful ESS linear accelerator"

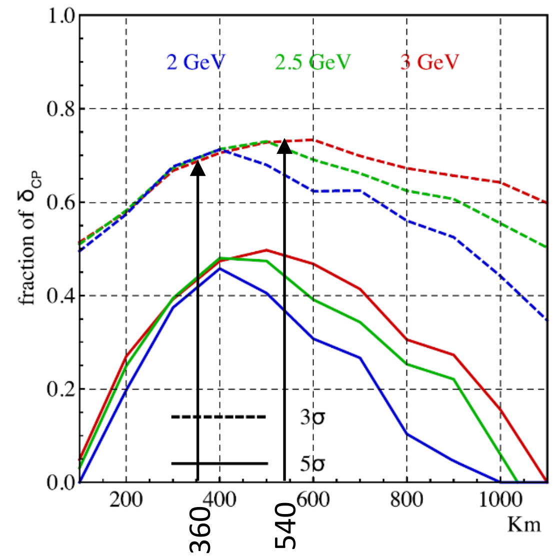
15 institutes from 11 European countries, including CERN and ESS

Measure δ_{CP} at 2nd oscillation maximum



P. Coloma and E. Fernandez-Martinez, arXiv:1110.4583v2

Prospective mine locations

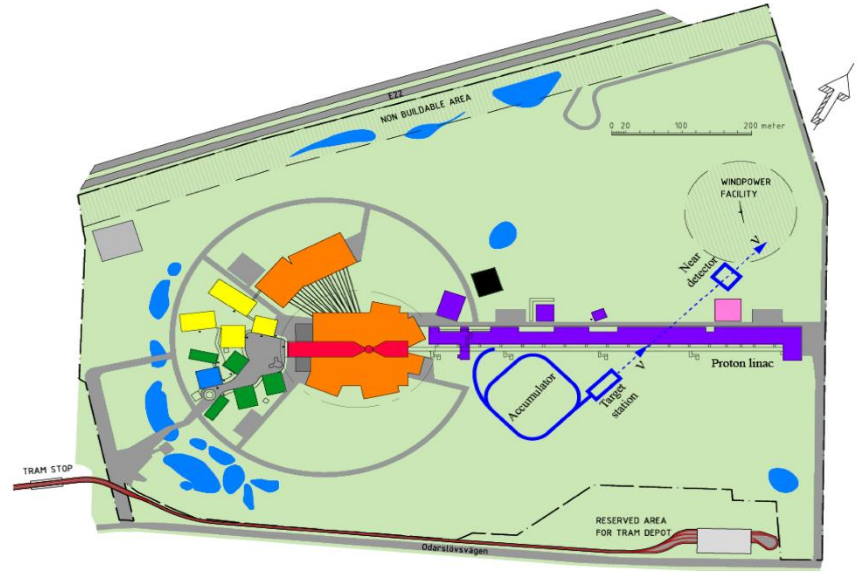


E. Baussan et al., Nucl. Phys. B 885, 127 (2014)

Introduction

- 2.0-GeV protons
- 5-MW beam power
- 14-Hz repetition rate, 2.86-ms pulses
- 10^{15} protons per pulse, > 10^{23} per year

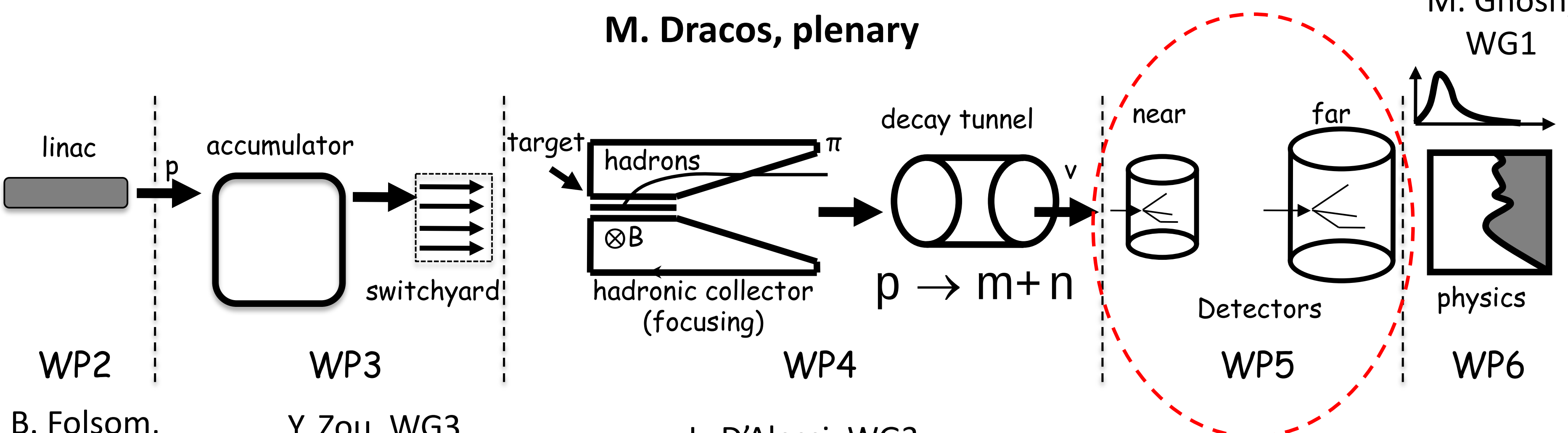
Upgrades desired for ESSνSB and other experiments



ESSνSB work packages and presentations at NUFACT 2019

M. Dracos, plenary

M. Ghosh, WG1



B. Folsom, WG3

Y. Zou, WG3

L. D'Alessi, WG3

This talk

The near detector (ND)

Characterization of the neutrino beam near the production point

- Energy and flavor measurement – neutrino flux
- Neutrino interaction cross section measurement

Aim: < 5% systematic uncertainties in signal/background normalization

5% signal, 10% background uncertainties assumed in white paper

[E. Baussan et al., Nucl. Phys. B 885, 127 (2014)]

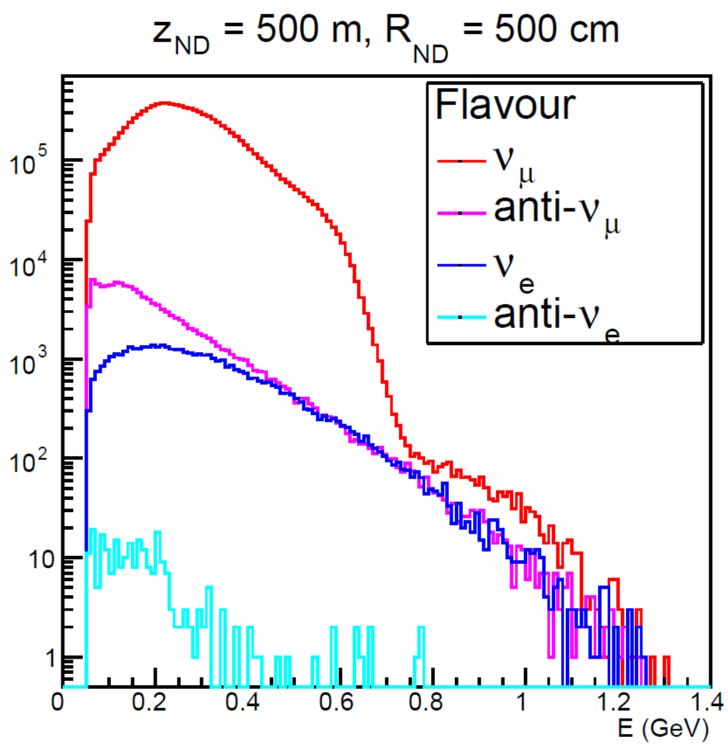
ND design criteria/requirements:

- Large mass to provide a sufficient number of neutrino interactions
- Acceptance for charged leptons (muons and electrons) in large scattering angle
- Capability to reconstruct and identify short tracks of low-energy hadrons around the interaction vertex

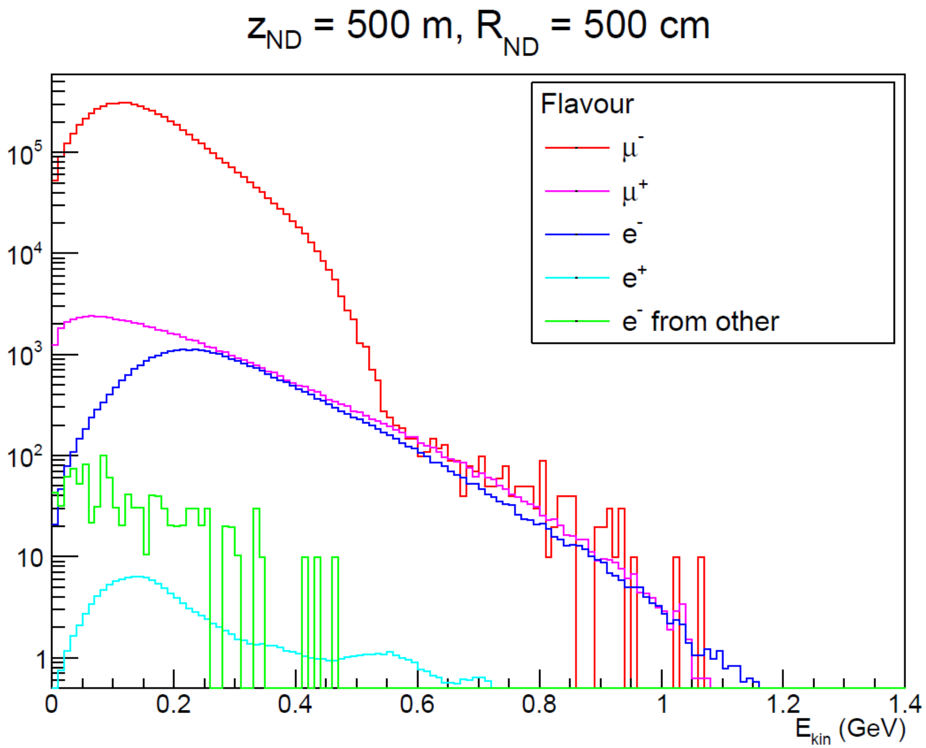
ND – background

Characterization of the neutrino beam near the production point

- Energy and flavor measurement – neutrino flux
- Neutrino interaction cross section measurement



Neutrinos/antineutrinos

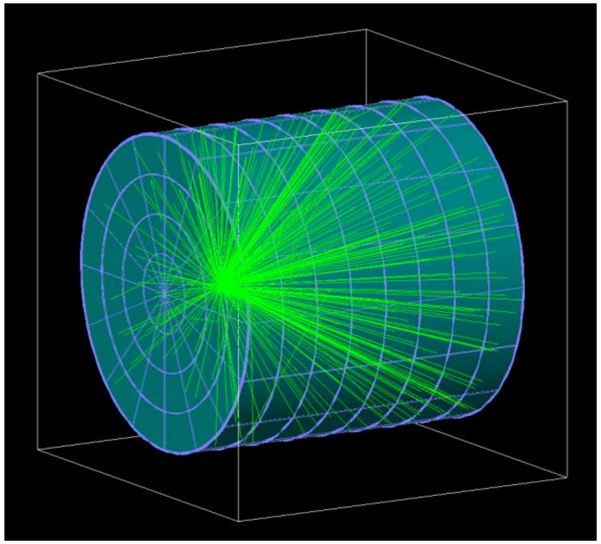


Charged leptons from neutrino interactions

A. Burgman, MSc thesis, Lund University (2015)

ND designs

Water Cherenkov detector



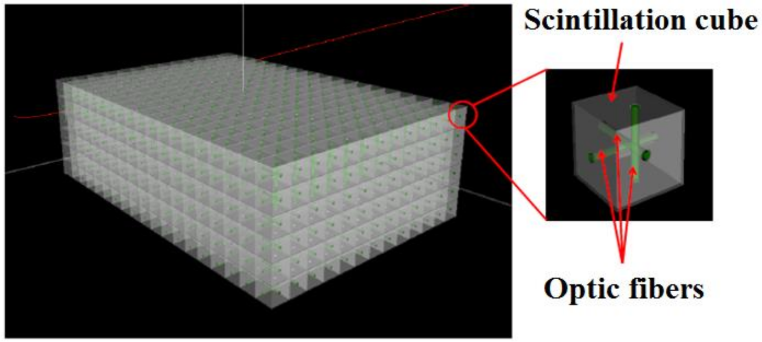
A. Burgman, MSc thesis presentation

PMT or LAPPD readout

Fiducial volume: 100-1000 tonnes

Simulations implemented in:
WCSim – Geant4 and ROOT-based water Cherenkov detector simulation, open source
EsbRoot – based on FairRoot framework

Super Fine-grained detector (SuperFGD)



A. Blondel et al., Jour. Instrum. 13, P02006 (2018)

$1 \times 1 \times 1$ cm^3 plastic scintillator cubes with wavelength-shifting fibers inside magnetic field

Mass: 1-10 tonnes

Tracking and momentum measurement

Simulated in EsbRoot

WC-ND development

Motivation: same neutrino interaction material and detection mechanism as for the water Cherenkov far detector (FD)

→ Possible reduction or cancellation in systematic uncertainties in energy reconstruction and flavor identification between ND and FD

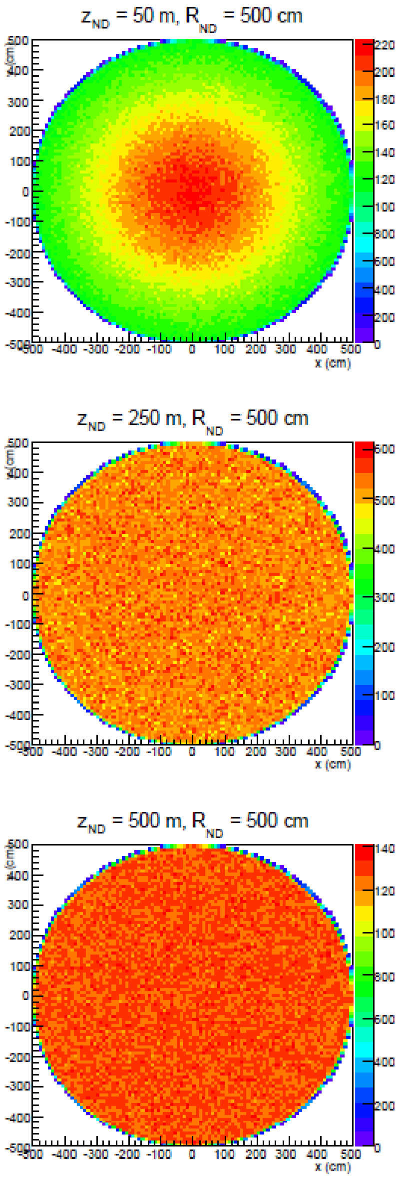
Questions to be addressed as a function of ND geometry:

- Which reconstruction algorithm, especially at < 200 MeV energies?
- Keeping neutrino flavor misidentification rates to << 1%
- Energy/momentum/vertex reconstruction performance

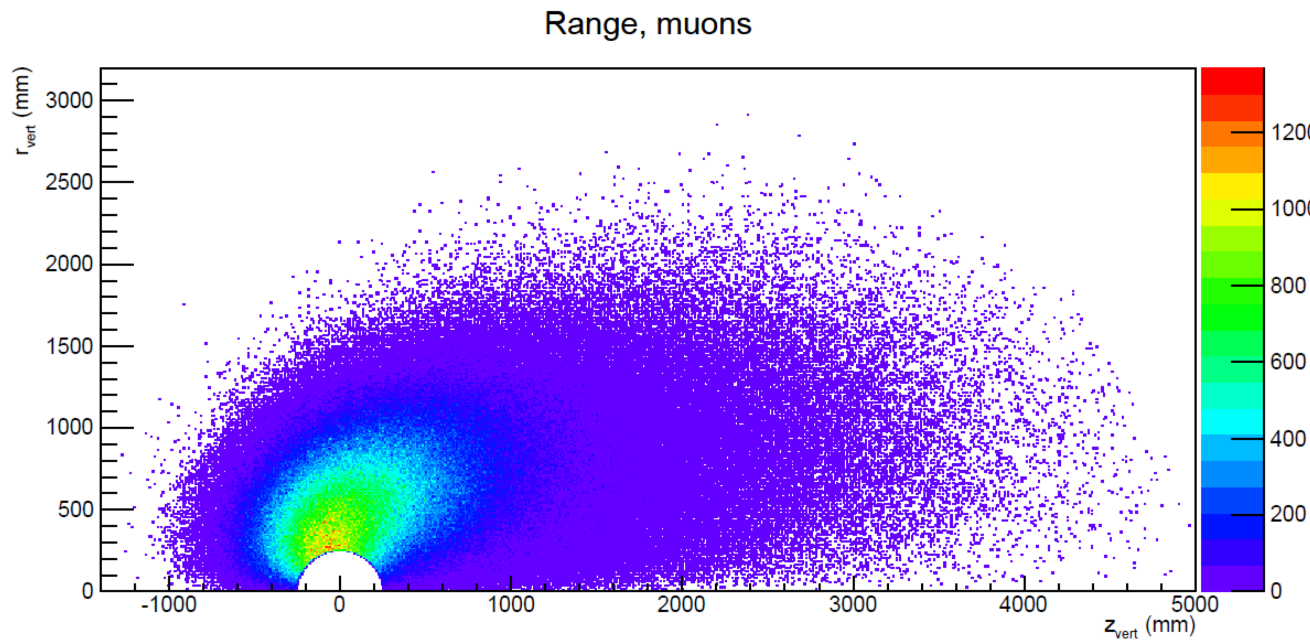
Several conclusions drawn from beam profile and charged lepton propagation in water (next slide)

Detector performance and geometry under investigation

WC-ND physical requirements



Neutrino spatial profile



- The length of the near detector: $L_{ND} \gg 3$ m.
- The radius of the near detector: $R_{ND} \gg 2$ m, $R_{ND} \leq \frac{z_{ND}}{50}$.
- The distance between the neutrino beam production and the near detector: $z_{ND} \geq 200$ m.
- The detector must have a space resolution smaller than 10 cm.
- The detector must have a time resolution shorter than 100 ps.

Conclusions from MSc thesis by A. Burgman, Lund University (2015)

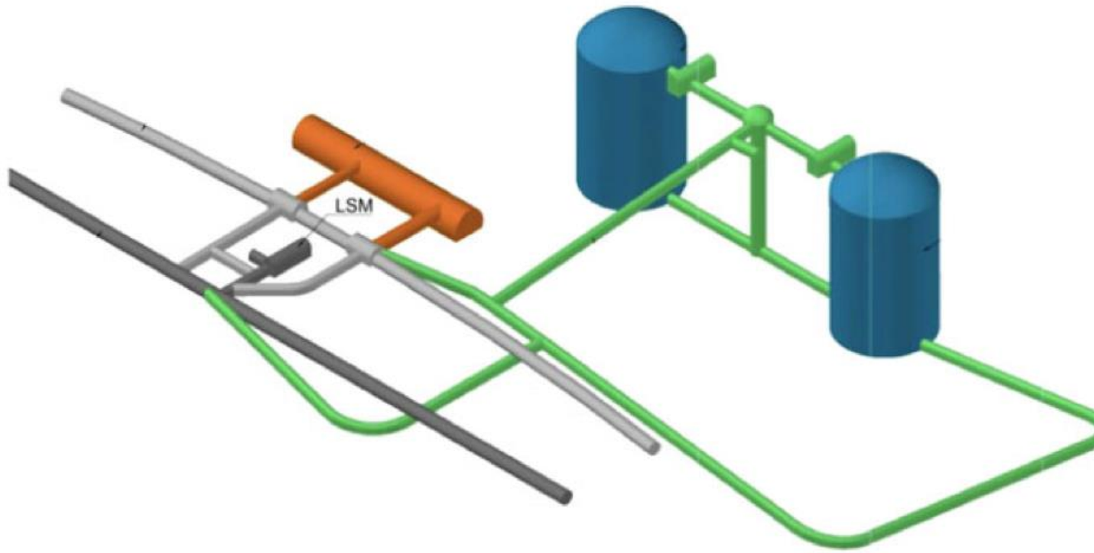
Z_{ND} = 500 m proposed for more shielding from cosmic background

The far detector (FD)

MEMPHYS-like Water Cherenkov detector

(MEgaton Mass PHYSics)

L. Agostino et al., Phys. Rev. ST Accel. Beams 16, 061001 (2013)



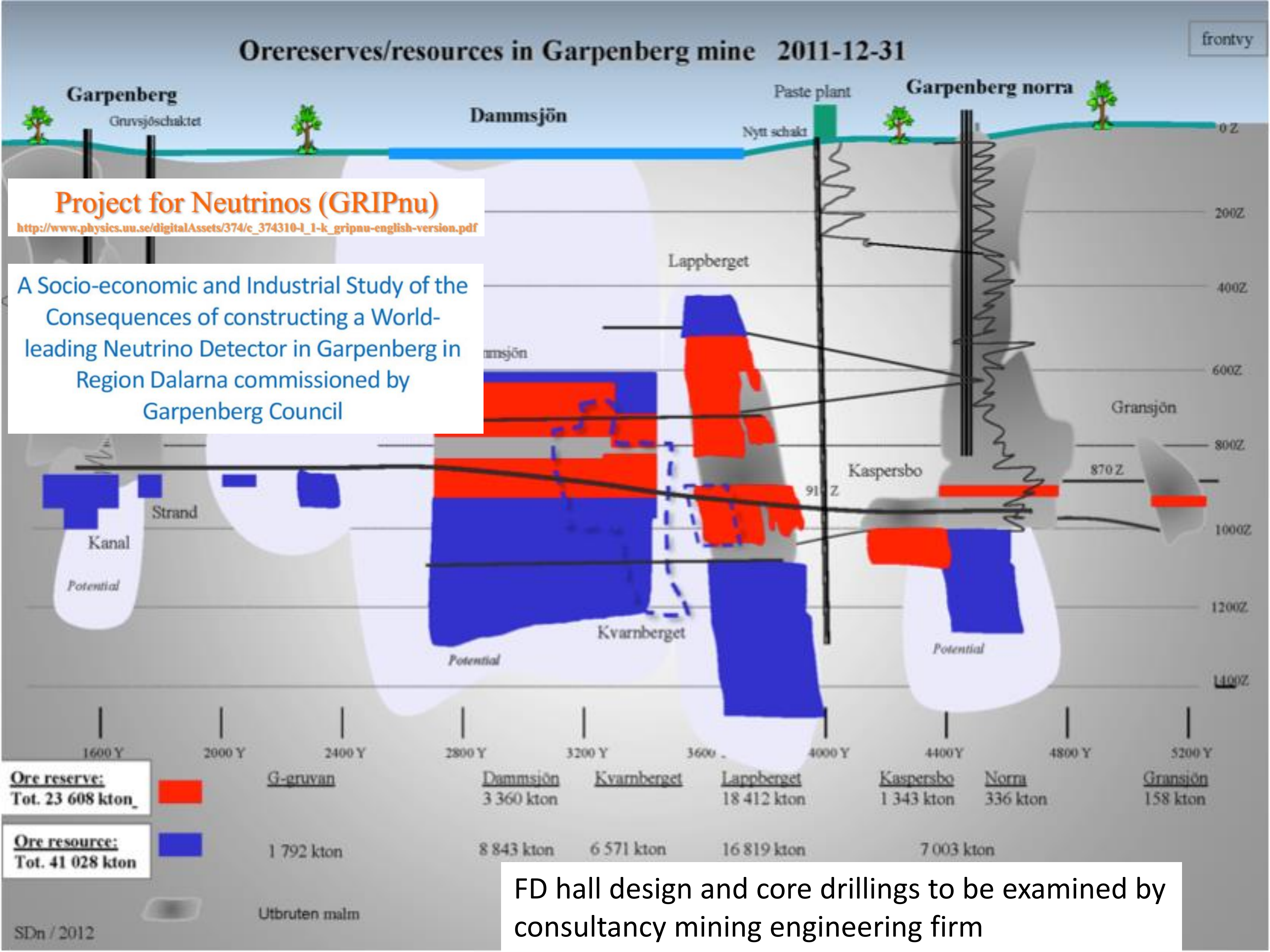
- Neutrino oscillations
- Proton decay
- Astroparticles
- Neutrinos from supernovae
- Solar/atmospheric neutrinos

500-kt fiducial volume (~20 x SuperK)
~240k 8-inch PMTs, 30% optical coverage
Cost: ~€700M

Project for Neutrinos (GRIPnu)

http://www.physics.uu.se/digitalAssets/374/c_374310-l_1-k_gripnu-english-version.pdf

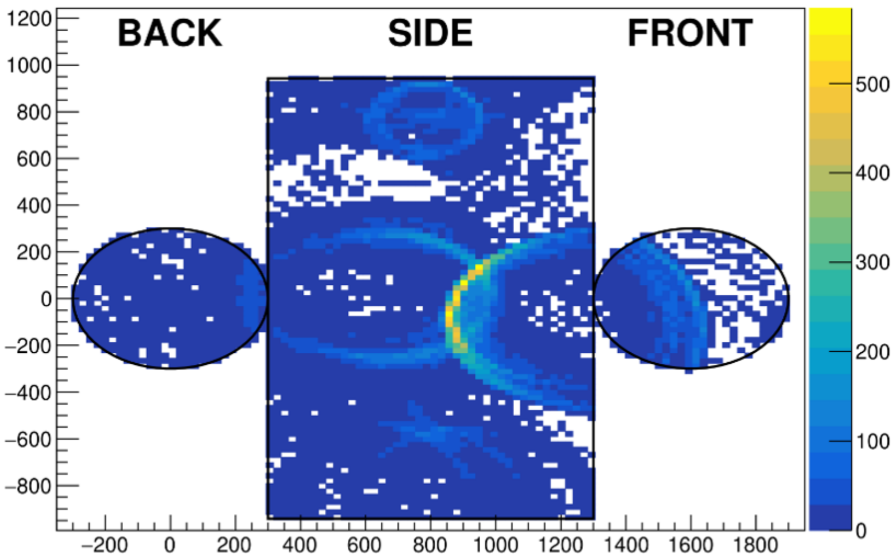
A Socio-economic and Industrial Study of the Consequences of constructing a World-leading Neutrino Detector in Garpenberg in Region Dalarna commissioned by Garpenberg Council

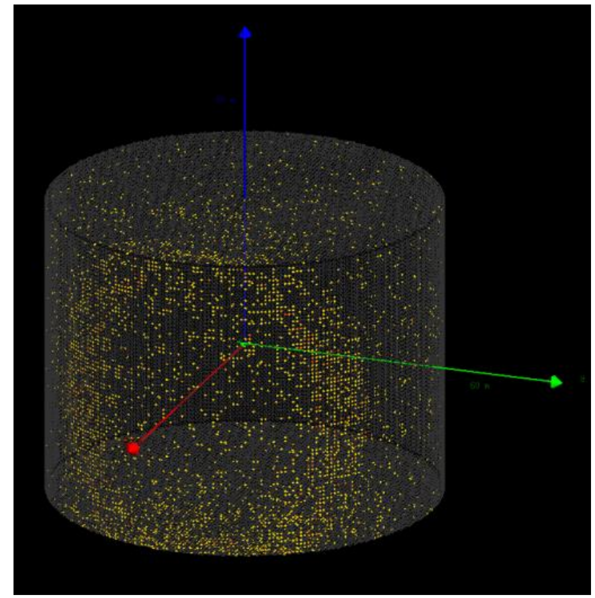


FD hall design and core drillings to be examined by consultancy mining engineering firm

FD simulations

Simulated in EsbRoot and WCSim event displays





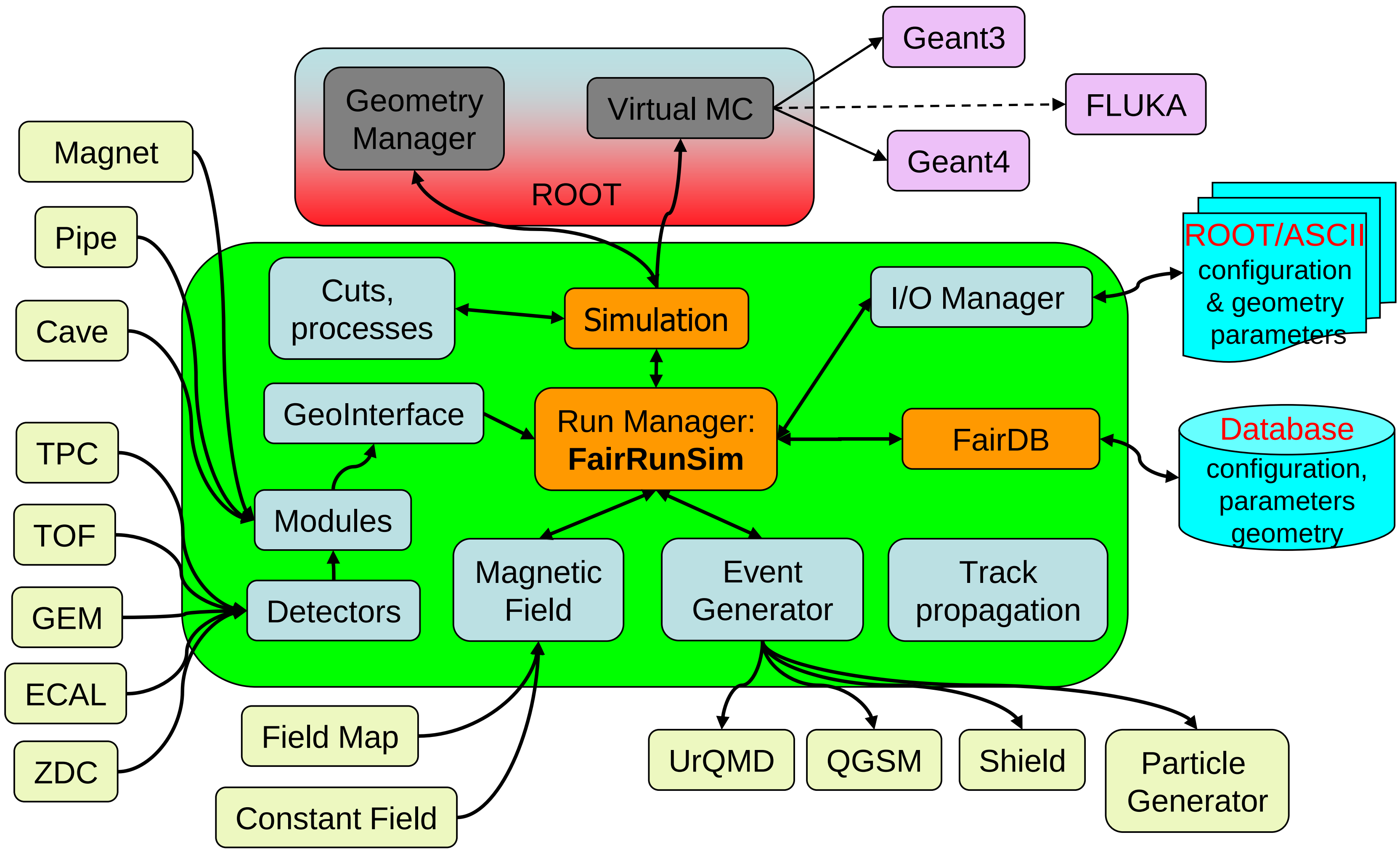
$$\nu_\mu + p \rightarrow \mu^- + \Delta^{++} \rightarrow \mu^- + p + \pi^+$$

$$E_\nu = 0.6 \text{ GeV}$$

- Charged lepton simulation and hit digitization complete
- Working on consistency in physics parameters and simulation output between EsbRoot and WCSim
- Assessing different reconstruction strategies and design dimensions

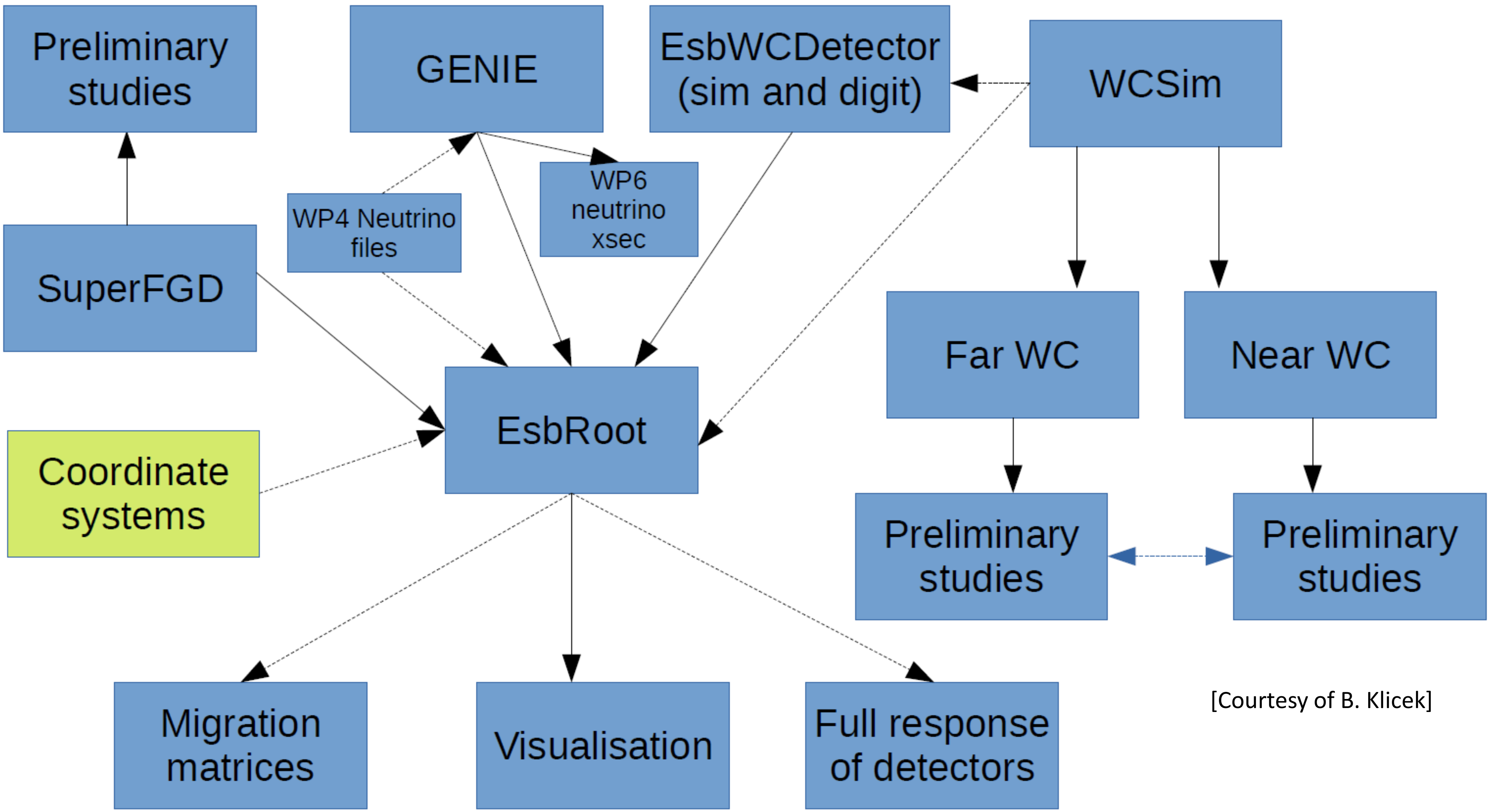
Software development - simulations

FairRoot framework (material from K. Gertsenberger, ESSvSB meeting in Strasbourg, 2018)



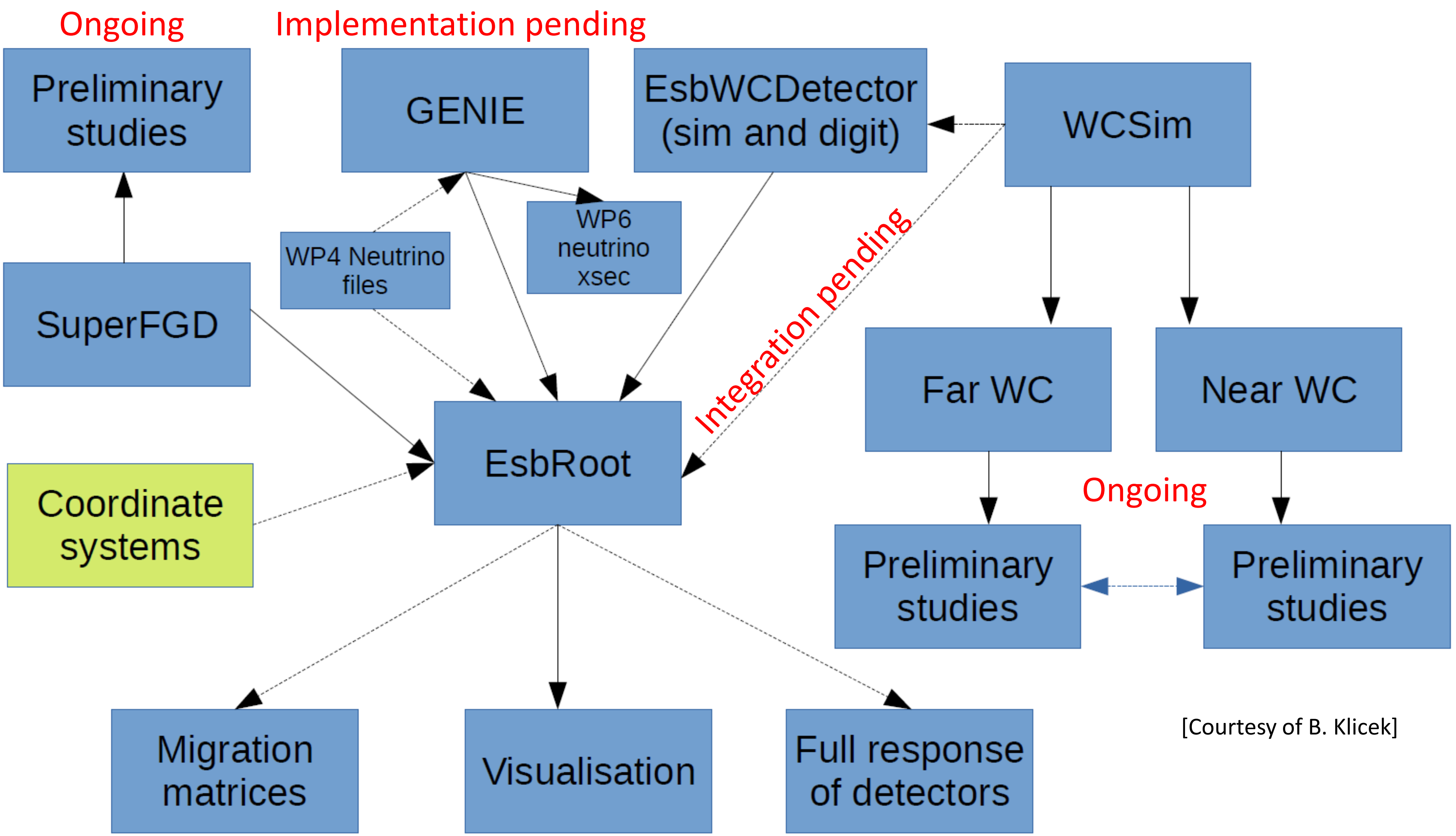
"EsbRoot" was developed for WP5 based on FairRoot framework

Detector software block diagram



[Courtesy of B. Klicek]

Detector software block diagram

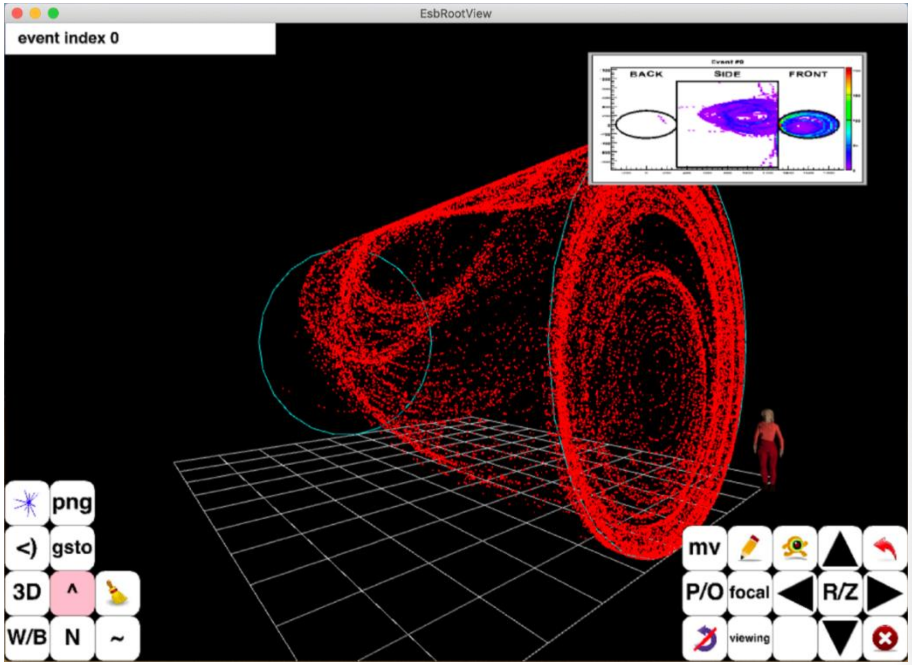


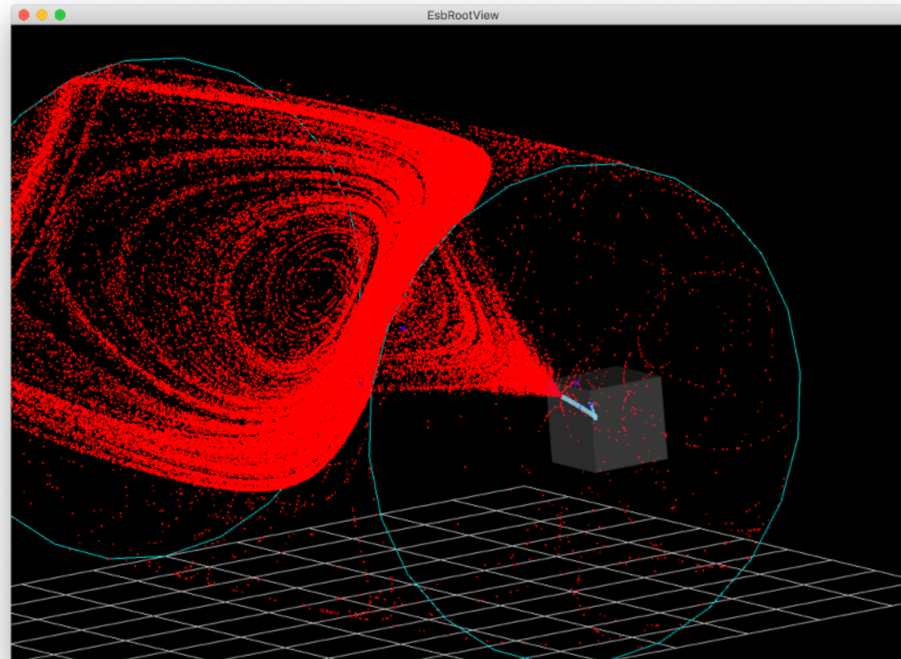
[Courtesy of B. Klicek]

3rd software workshop held in July 2019

Event display tool - EsbRootView

Courtesy of G. Barrand, CNRS/IN2P3/LAL





- 2D/3D event topologies
- Rotatable view
- Web browser/app development
- Timing information?

CCQE interaction inside SuperFGD, Chernkov radiation in water detector

Important cross checking tool for event reconstruction and PID

Summary and outlook

Initial designs and performance studies

- Water Cherenkov ND/FD
- SuperFGD tracker

Software frameworks

- EsbRoot, WCSim implemented
- Reconstruction algorithm under development

Tasks:

- Integrate GENIE Monte-Carlo neutrino interaction generator (arXiv:1510.05494) into EsbRoot
- Develop reconstruction algorithm for both ND and FD
- Finalize detector location, dimensions, components, and data analysis strategies

Design studies to be completed by the end of 2021
with a conceptual design report

Acknowledgements

ESSvSB WP5 collaborators:

G. Barrand, E. Baussan, M. Bogomilov, J. Cederkäll, P. Christiansen, M. Dracos, T. Ekelöf, G. Fanourakis, G. Gokbulut, B. Klicek, M. Oglakci, J. Park, G. Petkov, G. Stavropoulos, T. Tolba, A. K. Topaksu, R. Tsenov, and O. Zormpa

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