Fermilab Muon g-2

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Analysis development for the precision magnetic field measurement

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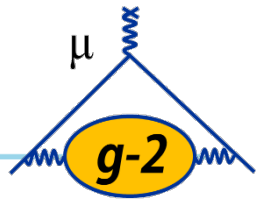
g-2 computing review

Nov. 8, 2016

Outline



- Our Goal
- Overview of B-field analysis project
- Our team
- Kick-off plan
- Current status
- Plans and schedule for the near future
- Summary

Our Goal

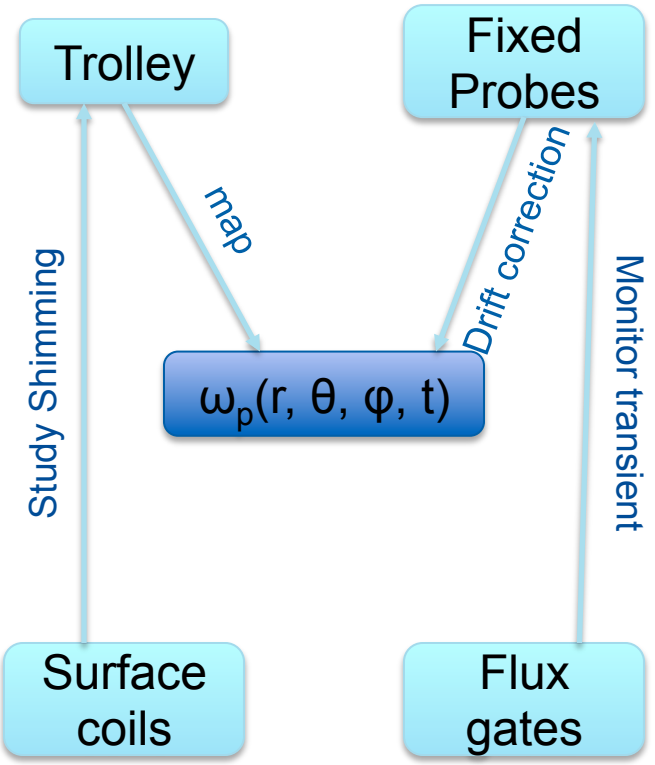
- Physics Goal
  - Provide $\omega_p(r, \theta, \phi, t)$ with absolutely solid uncertainty estimates $\Delta\omega_p(r, \theta, \phi, t) \leq 70$ ppb (weighted by muon distribution)
  - Provide the vector B field in the muon storage region

Source of uncertainty	R99 [ppb]	R00 [ppb]	R01 [ppb]	E989 [ppb]
Absolute calibration of standard probe	50	50	50	35
Calibration of trolley probes	200	150	90	30
Trolley measurements of B_0	100	100	50	30
Interpolation with fixed probes	150	100	70	30
Uncertainty from muon distribution	120	30	30	10
Inflector fringe field uncertainty	200	–	–	–
Time dependent external B fields	–	–	–	5
Others	150	100	100	30
Total systematic error on ω_p	400	240	170	70
Muon-averaged field [Hz]: $\widetilde{\omega}_p/2\pi$	61 791 256	61 791 595	61 791 400	–

Overview of the B-field analysis project

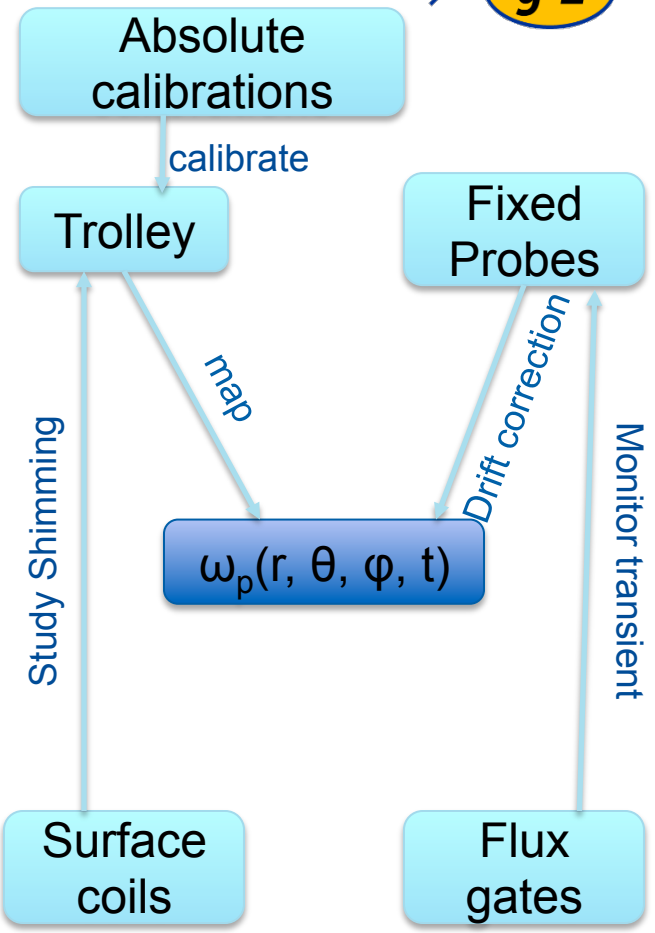
Hardware systems

- Trolley
  - Mapping ω_p in the muon storage area
  - Multipole expansion of the ω_p map
    - Slices vs azimuth
    - Average over azimuth
- Fixed probes
  - Monitoring ω_p in the outer region all the time
  - Correct drift of ω_p over time
  - Reminder of a trolley run
- Flux gates
  - Monitoring and correcting for the background field and transient field
- Surface coils – the Active Shimming
  - Monitoring the surface coil current
  - Understand how it shapes the field

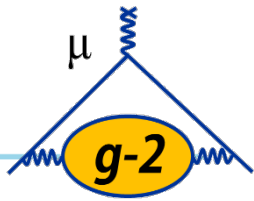


Overview of the B-field analysis project

- Absolute calibration
  - Correct the perturbations by materials
  - Correct for systematics like probe shape, chemical effects, imaging effects, etc.
  - Plunging probe: calibrate the trolley probes, in the g-2 ring
  - Water probe/ ^{3}He probe: calibrate the plunging probe, in the test magnet at ANL



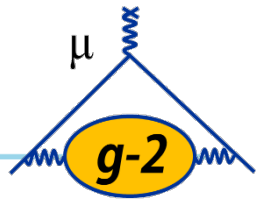
Overview of the B-field analysis project



Another “dimension” of the project (software systems)

- Online Analysis
  - Plot the fresh on screen
  - Automatic data quality monitoring, send alarms and reminders
- Offline Analysis
  - High accuracy/precision algorithms for extracting ω_p
  - Semi-offline: routinely executed analysis after each run (1 run scope)
    - Correlation study and first-order corrections
    - Construct data product useful for down-stream analysis
  - Commissioning Analyses: determine tunable parameters
  - Physical Analyses: reach the physics goal, full systematic study

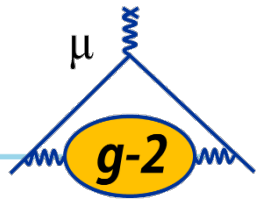
Overview of the B-field analysis project



Another “dimension” of the project (software systems)

- Data base
  - Record settings, health of each run, warnings, errors and alarms
  - Record key analysis results from online analysis
- Documentation: for normal operations and developments
- Software management
  - Repositories
  - System and network configurations
  - Development environment setup

Overview of the B-field analysis project

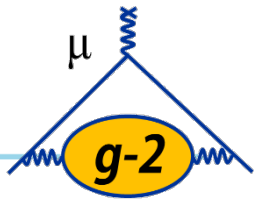


Tools for software systems

- Midas (DAQ)
- Art (Analysis)
- Html, css and java script (Display)
- MySQL or PostgreSQL (Data base)
- Doxygen (Documentation)
- Github and wiki page (Software management and documentation)
- Basecamp (Project management)

Our team*

Senior researcher/Faculty, Postdoc, Grad Student



- **Argonne National Lab:** *Trolley, Absolute calibrations (Platform)*
  - Peter Winter, Joe Grange, Ran Hong and undergraduates
- **University of Washington**: *Fixed probes*
  - Alejandro Garcia, Erik Swanson, Martin Fertl ,Matthias Smith, Rachel Osofsky
- **University of Michigan**: *Flux gates, Absolute calibrations (^{3}He)*
  - Timothy Chupp, Alec Tewsley-Booth, Midhat Farooq
- **University of Massachusetts**: *Absolute calibrations (water)*
  - David Kawall, David Flay, Alyssa Conway
- **Fermi Lab**: *Surface coils*
  - Brendan Kiburg and undergraduates

*These people are also busy with hardware, DAQ, shimming, radial field measurement, vacuum chamber alignment, etc. Only a fraction of their time can be spent on analysis for the moment.

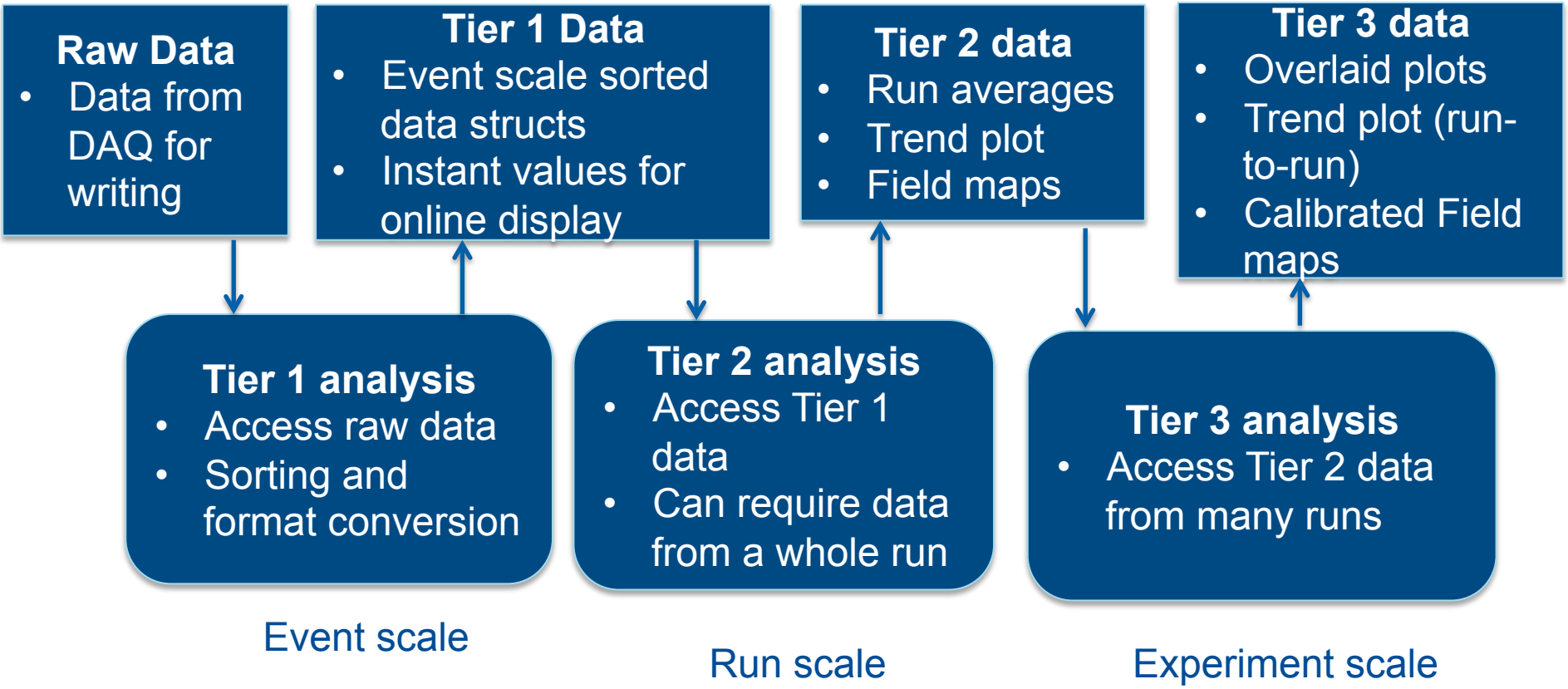
The kick-off plan

First Analysis Workshop, Argonne, June 29th – 30th 2016

- Status update from each hardware group
- Moderated discussions about: Requirements, tools, control logics, analysis framework, software management, etc
- Distill and make decisions

The kick-off plan

Generic Analysis Chain



The kick-off plan

- Decisions after the first Analysis Workshop
  - Appoint leaders for each hardware system and each software system
  - For each software system
    - Develop DAQ (may take >80% of their work)
    - Define raw and tier-1 data products
    - Define plots or numbers for online display
    - Define analysis tasks for online, offline and semi-offline
  - For software managers
    - Initialize github repositories for daq and analysis
    - Make decisions of which analysis tool to use
      - Discover midas anlyzer, rootana, rome, art
      - Study the gm2 offline computing software
    - Find the right way to configure virtual machine and development environment

Current status

Hands-on coding workshop, Argonne, Sep 13th-14th 2016

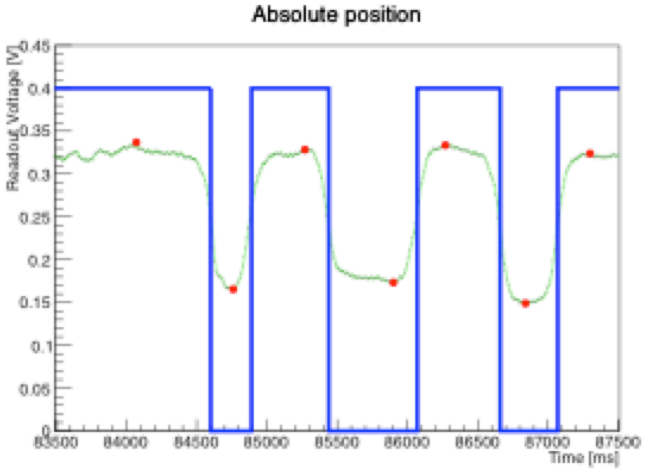
- Goal: make people familiar with setting up VM, using Midas and art
- Tasks
  - Training: VM setup and develop environment setup
  - Introduction to the git repository layout
  - Training: Midas set up, configuration and front-end development
  - Training: cvmfs, UPS and gm2 offline computing tools
  - Training: Art module development (with examples based on gm2 v6)
- Milestone: instruction materials become documentation for the tasks above

Current status

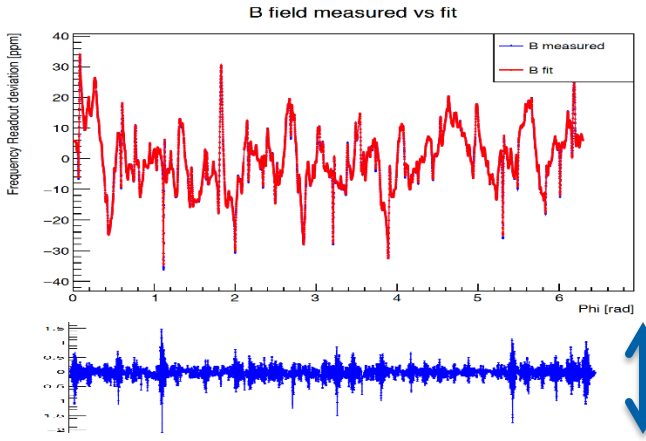
- More recent decisions
  - Move to gm2 v7 (Basic example of gm2 v7 was tested)
  - Use Midastoart for both online and offline (Thanks to Thomas for his development)
  - Use node and plotty (html, css , java script) for display (Thanks to Aaron for his development)
  - Use cvmfs and ups to setup utilities, like boost and root (Done!)
  - Reorganizing the online and offline systems
    - Online display and data quality monitor
    - Analysis modules
- Independent analysis developments: people's personal code
  - NMR signal fitting and frequency extraction
  - B field multipole expansion
  - Vector B field fitting
  - Trolley barcode analysis

Wrap into Art modules or programs with nicer interfaces

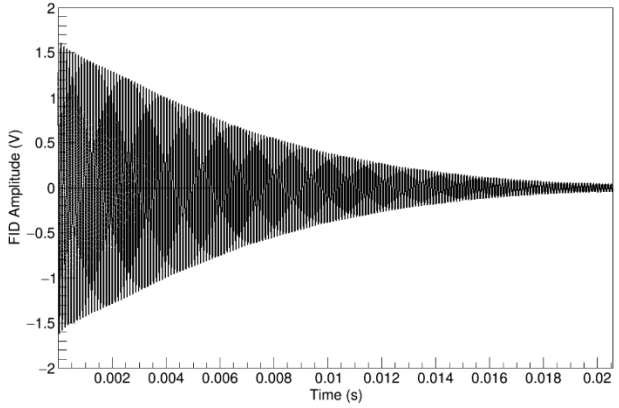
Current status

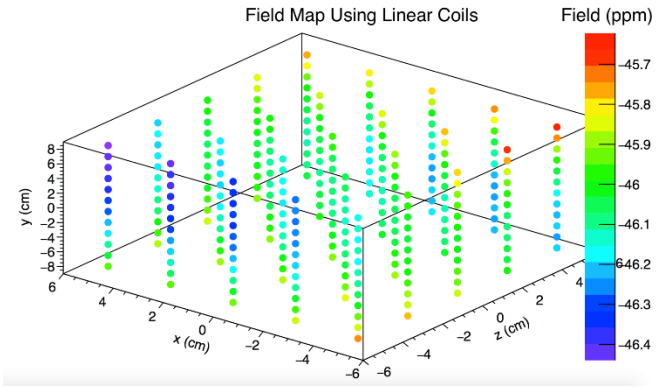


Barcode decoding



Vector B Field fitting

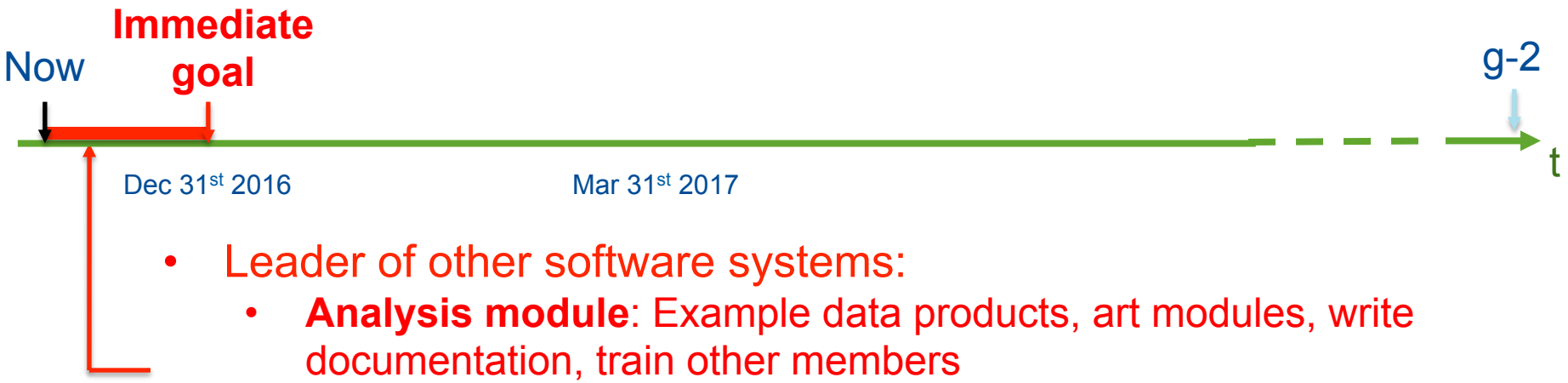




NMR frequency extraction and mapping the Test magnet

Future plans and schedule

- **Immediate goal**: Finish the “infrastructure construction” for the analysis software development



- Leader of other software systems:
  - **Analysis module**: Example data products, art modules, write documentation, train other members
  - **Online display and DQM**: Web page for display, templates for plotting, write documentation, train other members
  - **Data base**: Decide which server to use, setup a data base server, interface templates, write documentation, train other members

Future plans and schedule

Workforce chart

Software systems \ Hardware systems	Fixed probe (Matthias S)	Trolley (Ran H)	Flux gate (Alec T)	Surface coil (Brendan K)	Absolute calibration (David F)
Online display and DQM (Need Expert)	Matthias S	Ran H Peter W	Alec T	Midhat F	Ran H
Analysis module (Ran H)	Rachel O	Ran H Joe G	Alec T	Rachel O	David F
Data base (Need Expert)	Rachel O	Ran H	Midhat F	Rachel O	Midhat F
Documentation (David F)	Matthias S	Ran H Peter W	Midhat F	Midhat F	David F
Software management (Matthias S Ran H)	Matthias S	Ran H	Alec T	Rachel O	David F

Future plans and schedule

- **Immediate goal**: Finish the "infrastructure construction" for the analysis software development
- **Follow-up goal:** Each hardware team finish analysis development following the examples already set up

- Each team start their own development following the example
- Estimate that each system needs 1 week of development (DQM, analysis module, data base), expect to finish January 2017.
- **Milestone: Basic version of ω_p map extraction (Jan 2017)**

Future plans and schedule

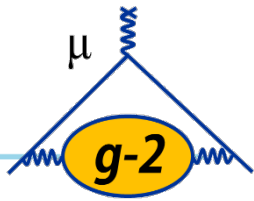
- **Immediate goal**: Finish the "infrastructure construction" for the analysis software development
- **Follow-up goal:** Each hardware team finish analysis development following the examples already set up
- **Near future goal**: Have the whole analysis software ready to extract the ω_p map when the B field is back on in 2017

- Testing and optimizing
- **Mock data challenge** using "simulated front-ends" (milestone)
- Develop more modules for correlations study and corrections
- **Milestone: Official version of ω_p map extraction**
  - All software development done
  - Well planned routine analysis tasks
  - Well documented

Future plans and schedule

- Towards the Physics Goal (Far future, >May 2017)
  - Most of the "products" from those tier-1 and tier-2 analyses are Root trees, histograms and graphs. Down stream analyses can be done without Art.
  - Restructure the organization, more "Physics Goal Oriented"
    - **Vector B field study**
    - **Systematics study**
    - **Convolution with muon distribution**
  - Two or more people doing the same task, for cross checking

Summary



- The precision B field analysis project is aiming at giving
  $\omega_p(r, \theta, \phi, t)$ and $\Delta\omega_p(r, \theta, \phi, t)$
- The project is initialized well and ramping up to speed. Tools are decided and people are starting to write code for data products and analysis modules
- Leaders of many important tasks are appointed, but we need experts on webpage (for plot/data display) development and data base development.