Performance

what we do and
what you can do for us

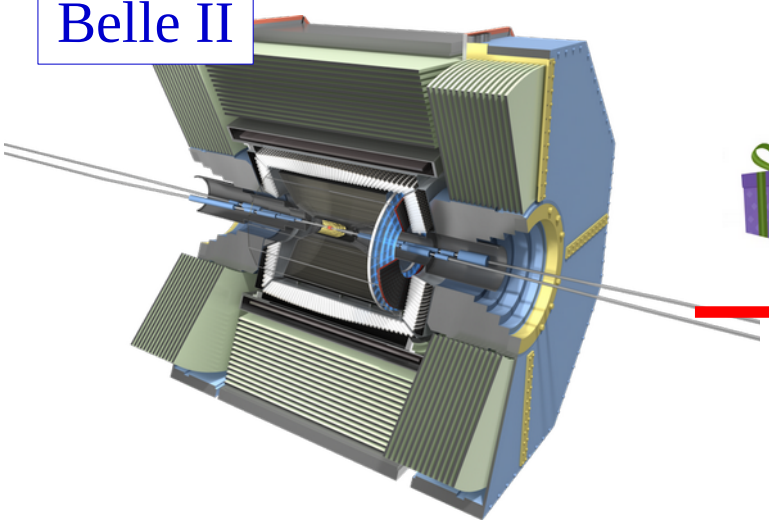
Alessandro Gaz

on behalf of the
Physics Performance Group

Physics Week
October 30th 2023

Who we are / what we do

Belle II



raw data

basf2
data production

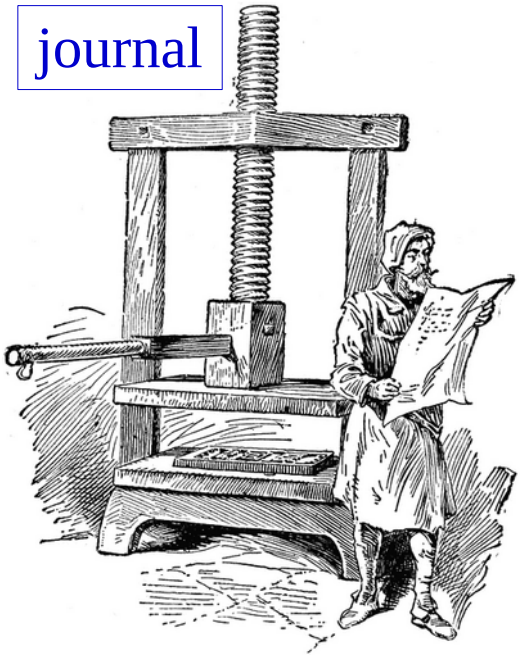
physics
objects

you

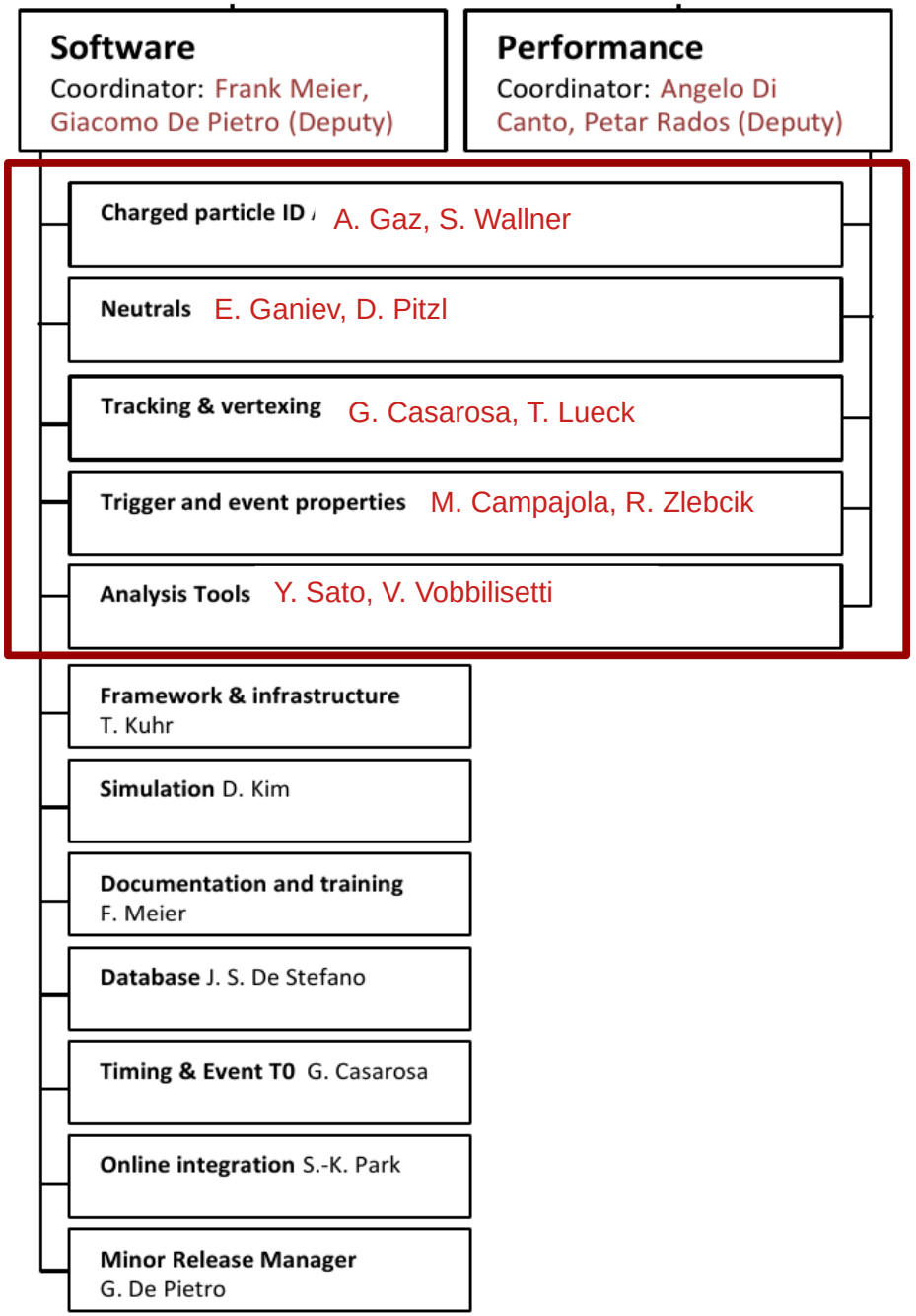
Oversimplified picture of how our experiment works

papers

journal



Who we are / what we do



- The performance group is aimed at connecting the detector experts with the physics analysis working groups;

  (we are not detector experts and we do not aim at producing physics results, our goal is to ensure that the process that leads from the raw data to physics analysis is the smoothest and most efficient possible)

- Our work has a lot to do with the software and this is why the performance subgroups also report to the software coordinators

  (since Spring 2023)

What we do

- Two main tasks:
  - Improve performance and/or our understanding of the performance
    - Including validation of new features in upcoming releases/data processings
  - Provide inputs and recommendations to analysts
    - Continue to move towards more automatization for the production of inputs to analysts

Angelo di Canto, Physics General meeting, Oct 16th 2023

What we provide

- We provide many inputs (e.g. the validation) behind the scenes so you can submit your ntuple production jobs, the software will pick up the correct calibration factors, you will get reliable physics objects, and you can concentrate on your analysis;

- Other times you can/should also directly approach us to get:
  - recommendations/recipes for your selection;
  - corrections to make the MC more similar to the data;
  - systematic uncertainties:
    - in some lucky cases (e.g. tracking efficiency), you get the number to put in the table of your Belle II note;
    - in most cases you will have to do some work

      (I'm sure Bruce will expand on this in his talk on Thursday);

- Please pay attention to the physics performance talks at the physics general meetings and B2GM, and you are always welcome to join our regular meetings!

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- Other times you can/should also directly approach us to get:
  - recommendations/recipes for your selection;
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  - systematic uncertainties:

Please do not underestimate the amount of work that is needed for systematics!

You should be able to provide, by the time of WG approval, at least the method you intend to pursue to determine them.

Does the performance group provide everything you need? Will the systematics be adequate (i.e. not limiting) for your analysis?

If not, you should contact us as soon as possible!

- meetings and B2GM, and you are always welcome to join our regular meetings!

What we need from you

- Belle II (detector, software, …) is continuously evolving, we need to make sure that everything is working correctly (we have to anticipate that the performance might deteriorate due to backgrounds or detector aging, with larger data sets some systematic might become limiting, so we need to update our methods, …)
- Belle II has not yet reached its ultimate performance, there are new ideas that we want to try to extend our physics reach;
- Some tasks are common to many analyses and are tedious/repetitive. With better tools we can make everybody's life easier (and less prone to mistakes);

To achieve all this we need person-power (that is: you guys) and fresh ideas!

Service tasks in Belle II

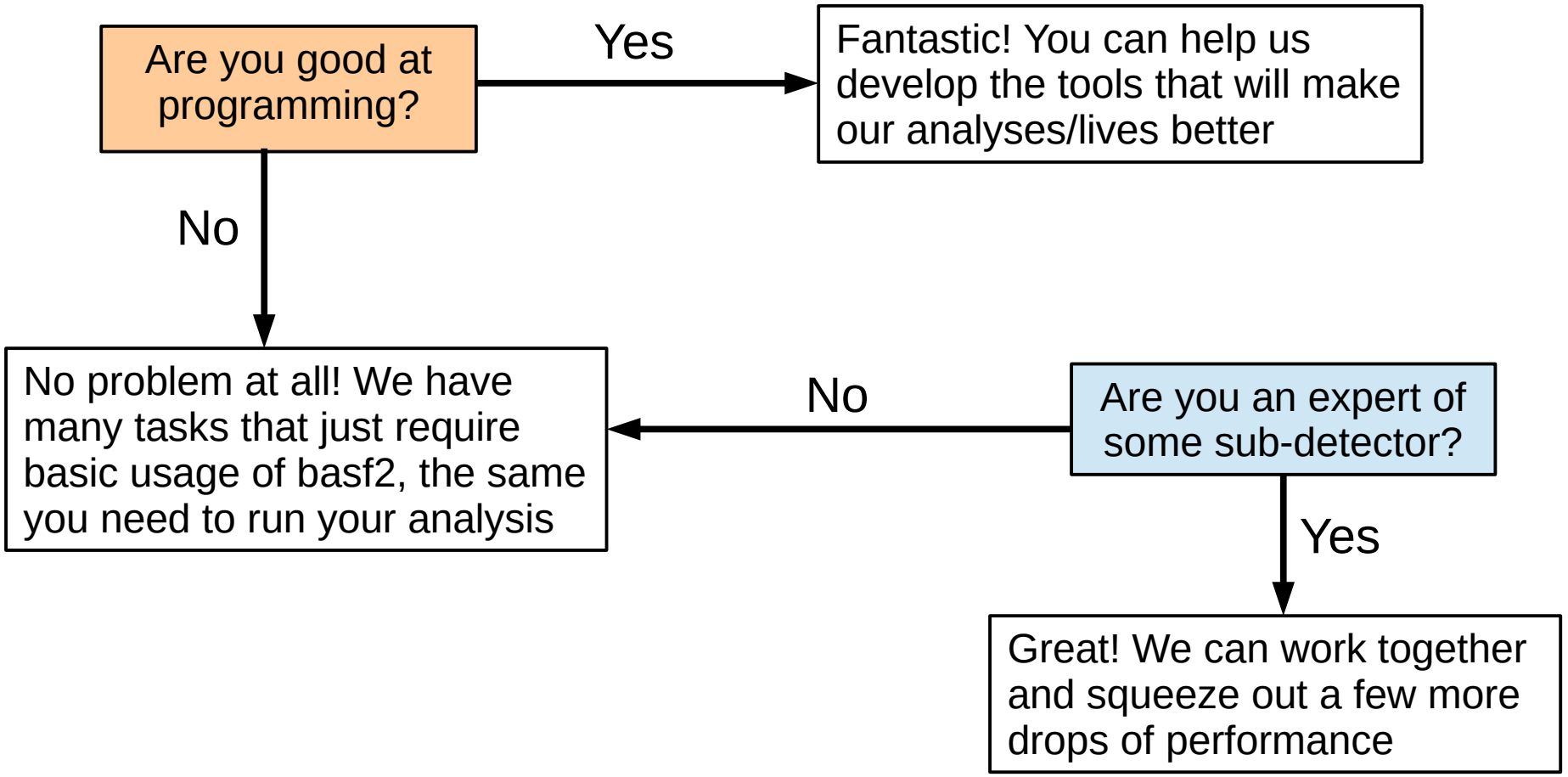
From the Belle II bylaws:

16.2 Members in the Physicist—faculty/staff, Physicist—term limited, and PhD student categories must devote 6 months equivalent of their research time to service work prior to becoming authors. The nature of the work should be negotiated with Belle II management. After the completion of this work, the Publications Committee will add the member to the author list upon the request of the IB representative and agreement of the relevant convener or coordinator.

Luckily you can count on us (and also on other groups), we have plenty of service tasks to help you to becoming a Belle II author!

Service tasks in Belle II

- There are many kinds of service tasks, and finding something that matches your interests and skills will not be difficult;
- For example:



(Unsolicited) advice

- It is good to choose something related to your analysis or to the activities of your group. However, try to step out of your “comfort zone”:
  - you will learn more!
  - you will expand your horizons;
  - you are likely to get somebody who will write for you a nice letter when you will be applying for your next position;

- Do not be afraid to take “important” tasks:
  - you might feel some pressure, but...
  - … the more people need your work, the more likely you are to receive help if you run into trouble;

- Remember that we are working for the same experiment: your success is also everybody else’s success!

Available tasks in Charged PID

A. Gaz, S. Wallner

A variety of different service tasks is available:

- technical/programming;
- event selection;
- statistical methods;
- machine learning;
- …;

The Systematics Framework

- The Systematics Correction Framework is a key tool for Belle II analysis;

- Samples relevant for PID:
  - $D^{*+} \rightarrow [D^0 \rightarrow K^- \pi^+] \pi^+$;
  - $\Lambda^0 \rightarrow p \pi^-$;
  - $K_S \rightarrow \pi^+ \pi^-$;
  - $J/\psi \rightarrow e^+ e^-, \mu^+ \mu^-$;
  - $e^+ e^- \rightarrow e^+ e^- (\gamma)$;
  - $e^+ e^- \rightarrow \mu^+ \mu^- (\gamma)$;
  - $e^+ e^- \rightarrow e^+ e^- l^+ l^-$;
  - $e^+ e^- \rightarrow [\tau^+ \rightarrow 3\pi\text{'s } \nu][\tau^- \rightarrow l^- \nu \ \nu]$;

We have been using these for a while now

We are getting there, and plan to include all these samples into the SF by next Summer

Several service tasks available!

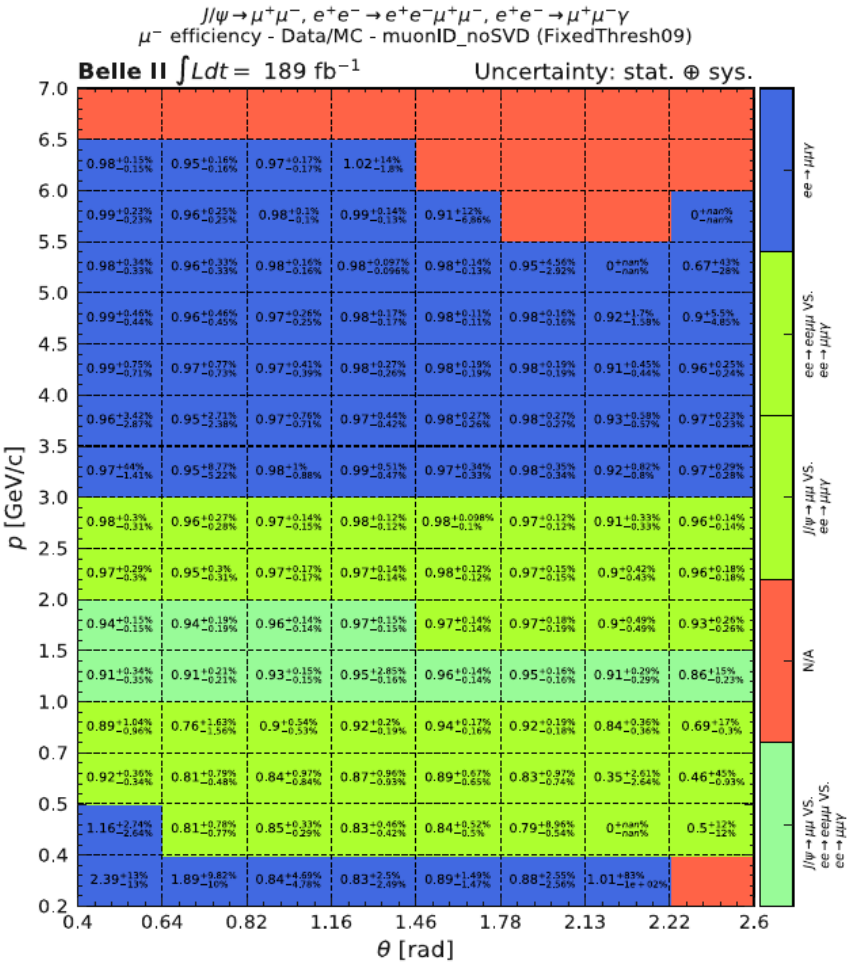
We have stuff for both skilled programmers who can help Sviat in the development of the tool and less software / more physics oriented jobs for the validation and study of the systematic uncertainties of the new samples.

Bin-by-bin correlations in lepton ID

- This is a clear example where a tight connection between analysis and performance will bear fruits!

- Problem: we calculate efficiency corrections in bins of (p, θ), and each bin in the table comes with a statistical and systematic uncertainty. We want to precisely determine the correlations among the different bins in order to reduce the systematics from PID;

- Still in exploratory phase (we learn as we go), but likely to be a multi-step process:
  1) "Measuring" the correlations (e.g. with bootstrap);
  2) Understanding the individual sources of uncertainty and properly model their correlations.



For more details, please see this talk by Marco Milesi.

Miscellaneous tasks

Other tasks (some of them small and can be merged to total the 6 months FTE):

- Validation of new software / tools;
- Development / testing of new multivariate methods
  (6-particle discrimination with Neural Networks);
- Production of ntuples / maintenance of skim code for PID studies;
- Improvements of the sub-detectors' likelihoods (are you a detector expert?);
- Systematic uncertainties:
  - ➔ compatibility of PID performance on different samples;
  - ➔ fit quality in regions with poor performance (e.g. backward, outside TOP acceptance)

Is your analysis limited by PID? Come talk to us!

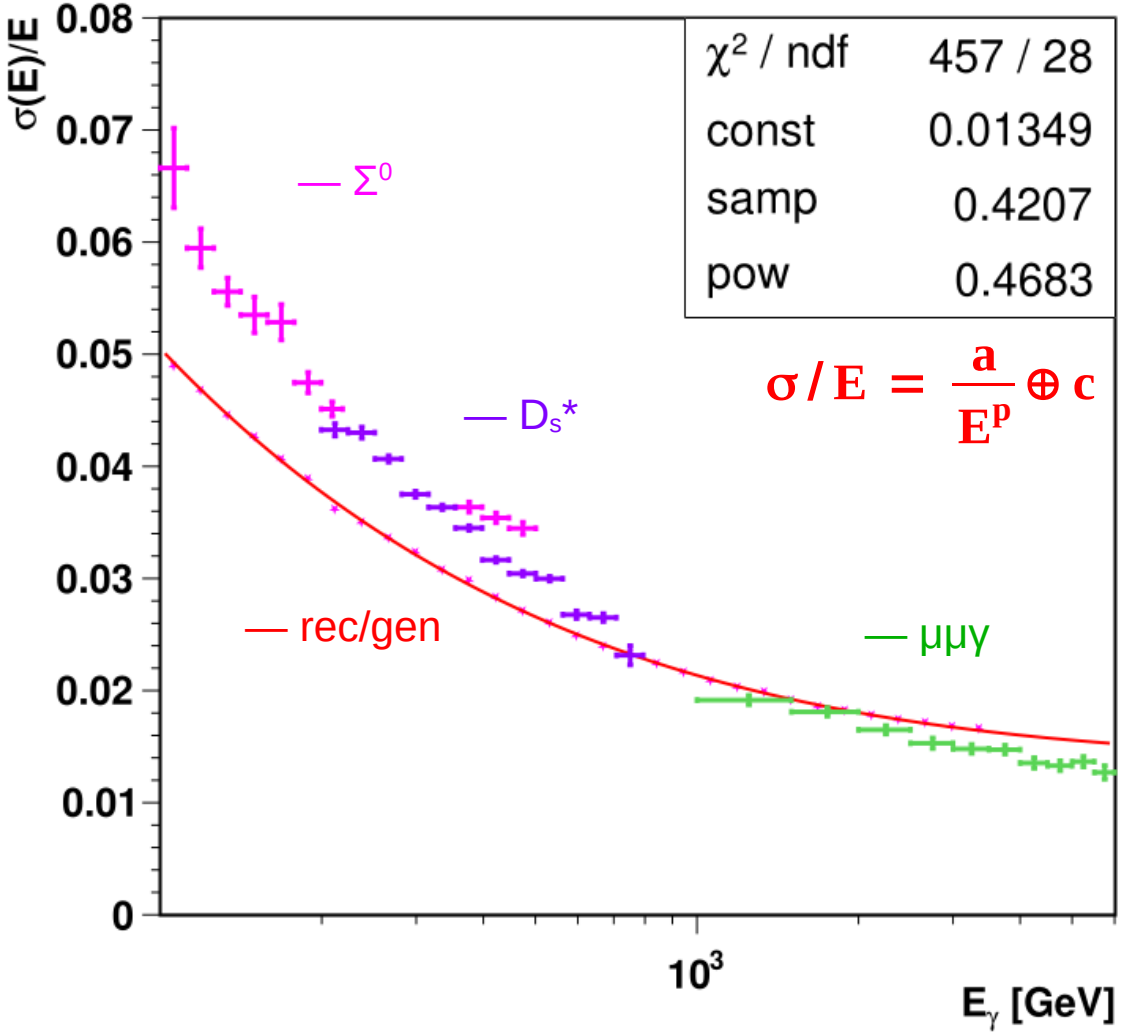
Service task topics in Neutrals

Daniel Pitzl, DESY

Belle II performance, 25.10.2023

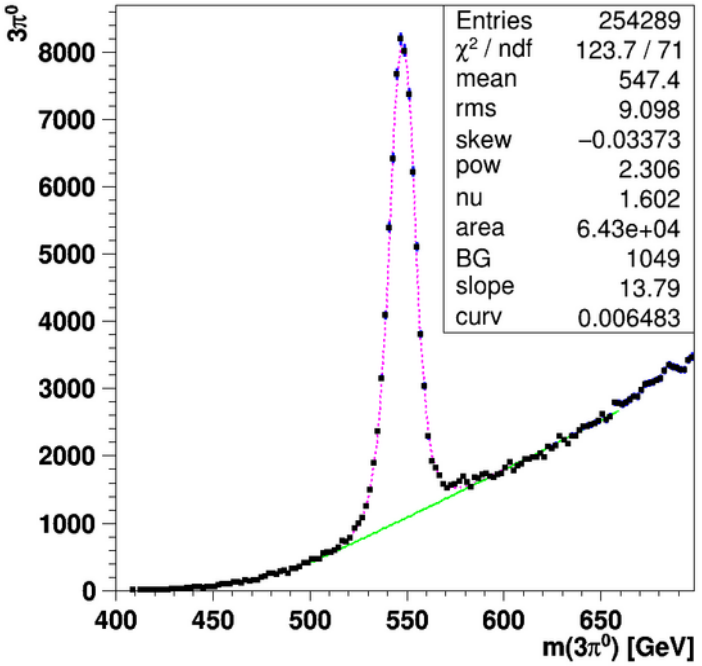
- photon energy resolution
- π^0 efficiency from η decays
- material budget from photon conversions

photon energy resolution

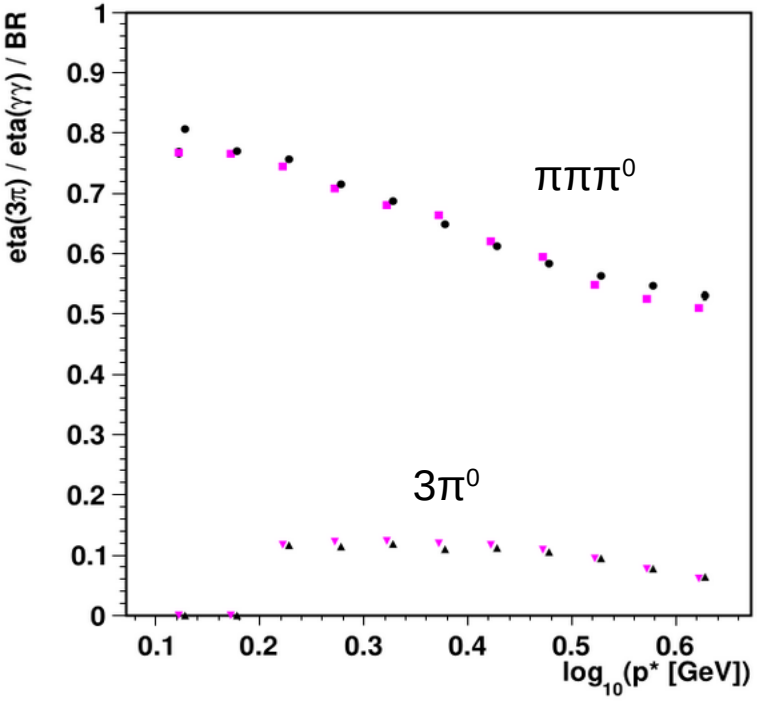


- photon energy resolution:
  - needed for kinematic fitting in decay chains
  - (also need photon angle resolution, and correlations)
- μμγ being done at Karlsruhe
- extend to lower energies using photons from excited hadrons:
  - unfold energy (and angle) resolution from mass peak width
  - data and MC

π^0 efficiency correction from η decays

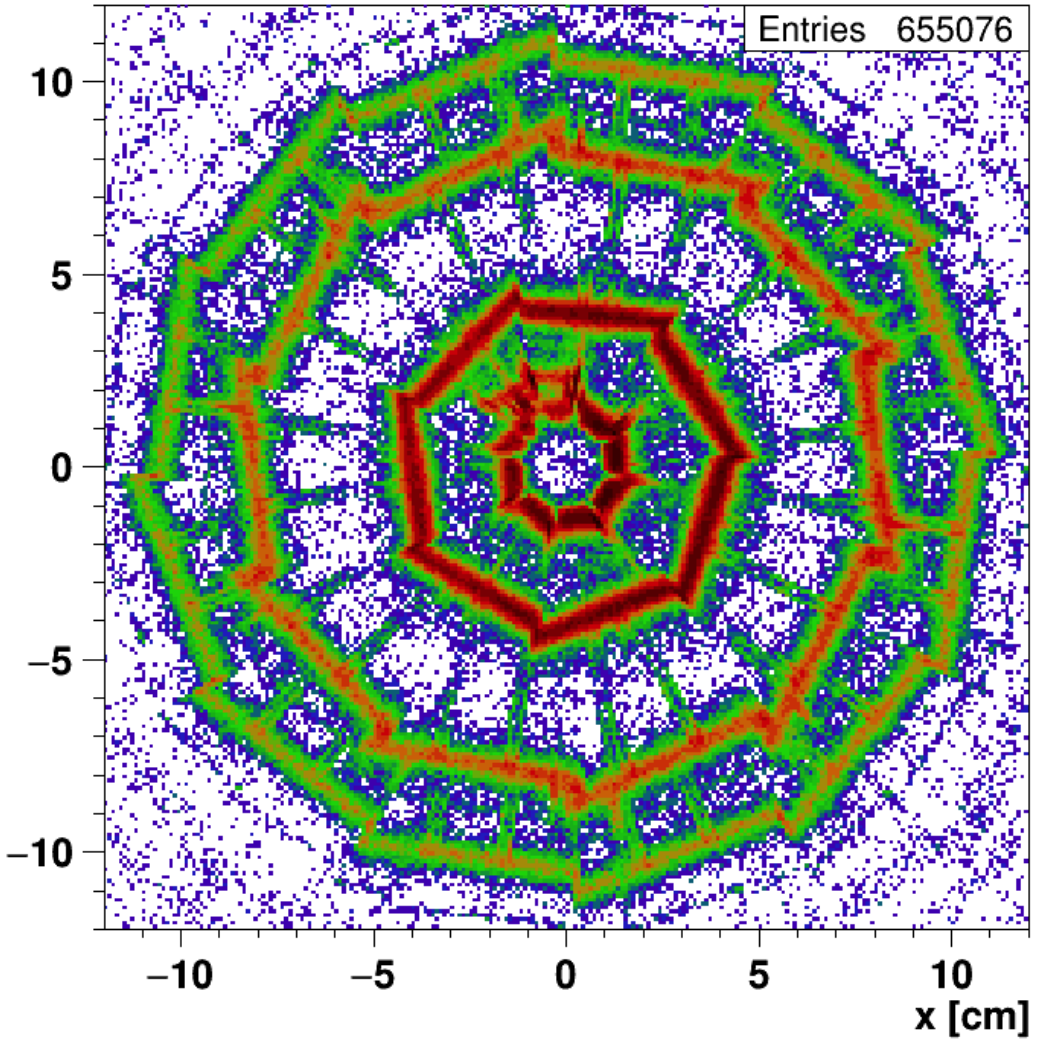


- select $\eta \to \gamma\gamma$, $3\pi^0$, $\pi^+ \pi^- \pi^0$
- ratio of yields / BR → efficiency ratio
- data/MC double ratio → correction



- systematics:
  - 0.7% or 1.6% from BR
  - ?? from fitting function

photon conversions



- photon conversions in the tracker material:
  - select and fit displaced e^+e^- pairs
  - material budget imaging
- MC vs data:
  - quantify (dis)agreement
- conversion: clean source of electrons:
  - for particle ID and ECL studies

Tracking & Vertexing Service Tasks

Giulia Casarosa, Thomas Lueck

rules here

Contributing to Tracking & Vertexing

- a high quality tracking & vertexing is critical for the vast majority of our physics program
- there are several ways to contribute to a better tracking & vertexing for BelleII:
  a. computation of the **corrections & systematic uncertainties** → needed after every major production (next in line is proc16+prompt & MC16) (systematics)
  b. **understanding details of the performance** and of the data-MC differences → improve tracking & vertexing itself, reduce the systematics (performance)
  c. **software improvements** for future major software releases → improve tracking & vertexing performance, increase robustness against background, improve tracking of certain classes of tracks, reduce systematics (next in line is release-09) (software)
- contact Giulia & Thomas in case you have any kind of question!

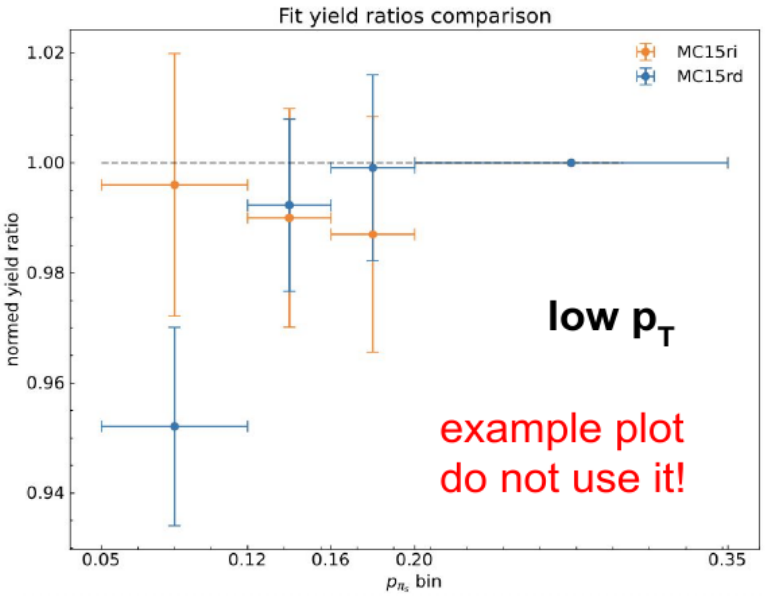
an example, more in backup

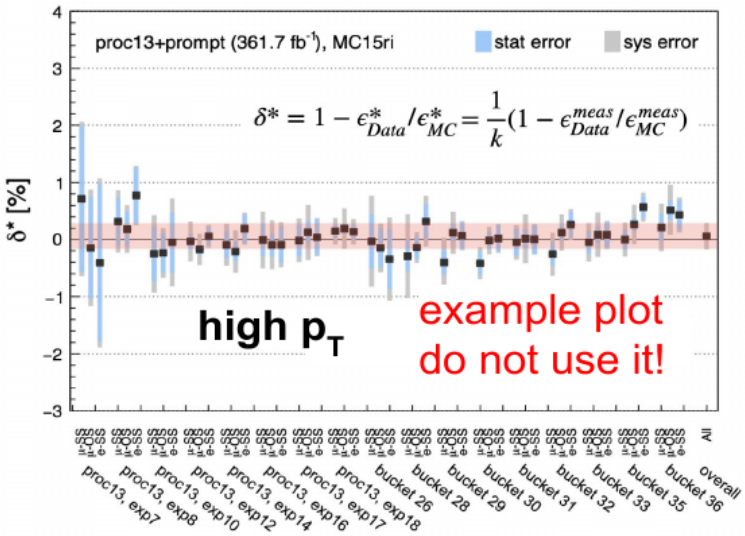
Contribution to Tracking Systematics

low & high momentum tracking efficiency corrections to MC (2 tasks)

- well established and documented procedures
- implement VIBE scripts to automatize the procedure as much as possible
- validate the procedure to the larger dataset that will be available
- produce proc16+prompt vs MC16rd results
- document the study and results in a dedicated technical note

https://confluence.desy.de/display/BI/Tracking+and+Vertexing+Performance



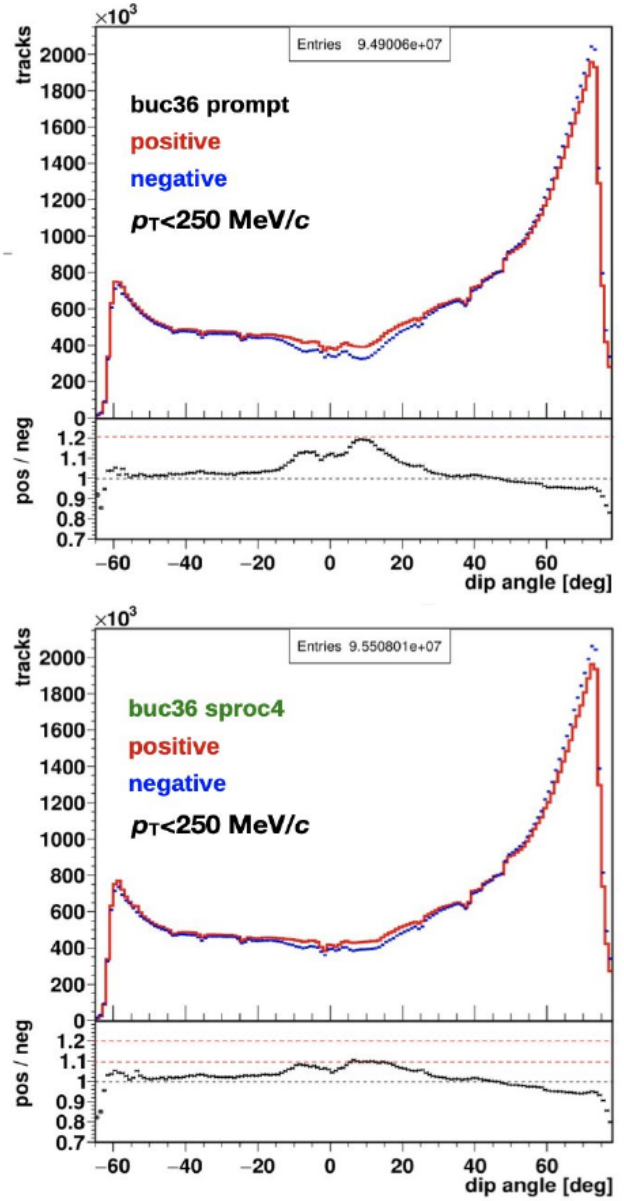


an example, more in backup

Contribution to Tracking Performance

significant charge asymmetry observed in data and MC for low momentum tracks in the transverse plane

- understand the origin of the asymmetry to then improve the software at the origin
- requires to look at low-level and detector-related quantities
- unexplored territory, potentially a lot of fun!



an example, more in backup

Contribution to Tracking Software

- Tracks in mDSTs have a quality indicator (QI) that help in track selections for analysis

MC14ri	Primary eff.	Prim. & sec. eff.	Fake rate	Clone rate
No QI	93.97%	79.66%	3.83%	6.36%
CDC QI > 0.9	**94.18%** +0.2%	**77.12%**	**3.22%**	2.57% –3.8%

- track QI are computed with MVAs using track-level information
- we have a QI for CDC-tracks, but the performance need to be updated to the latest release (see table above from this)
- we should improve the VXD-tracks QI
- we should then combine them in a global track QI to be stored in mDST

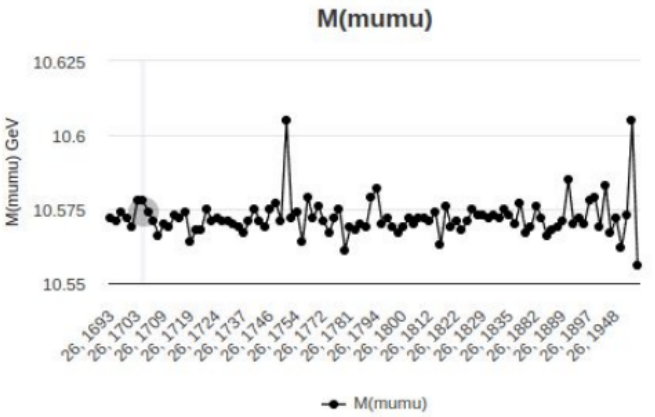
https://confluence.desy.de/display/BI/MVA+Track+Quality+Indicator

Trigger and Event properties Service tasks

Marcello Campajola, Radek Žlebčík
26 October 2023

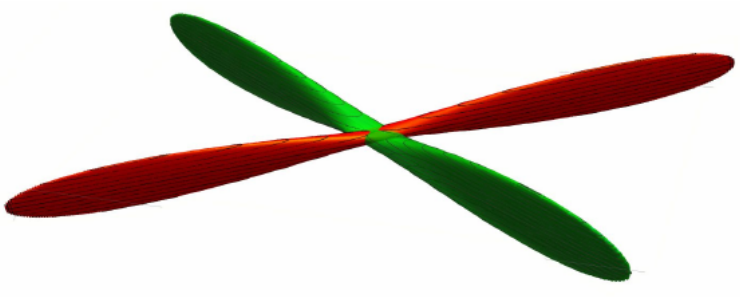
Online measurement of CM collision energy

- Prompt knowledge of the collision energy and/or B meson yield per luminosity is crucial for maximizing the performance of the B factory
- There has been progress in the offline measurement of these quantities, however the online determination within the MiraBelle is still missing, the only available entry is the $M_{\mu\mu}$



Beam Spot & Boost Vector systematic uncertainties

- There are many analyses measuring the lifetime or related to TD-CPV that use beam spot constraint to improve the resolution of the vertices
  → The uncertainty has been only studied using MCri samples
- Study of the systematic uncertainties of these two calibrations using run-dependent MC samples (MCtruth vs MCreco correspondence)
- Finalize the framework that allows for systematic shift of the calibration parameters for the MCrd so that the uncertainties can be easily propagated to the user's analyses



Analysis Tools

Yo Sato, Vidya Vobbilisetti

Service tasks for Flavor Tagger

- Retraining and maintenance of Flavor Tagger
  - Goal: Keep and enhance the GFlaT performance for new and reprocessed data .
  - Target: MC16 and proc16+prompt = 2024 summer
  - Tasks:
    - Make a pipeline of the training process.
    - Retrain Flavor Taggers using MC16 samples. Update software tools as well.

- Calibration of Flavor Tagger parameters for B+ modes. (collaborate with activities on B0)
  - Goal: Evaluate the GFlaT performance with B+ modes as referenceable results.
  - Target: 2024 summer
  - Tasks: Evaluate the GFlaT parameters.

Service tasks for other analysis tools

- Validation of Brems-correction tools
  - Improve energy-momentum resolution of electrons.
  - Goal: Evaluate efficiency, momentum resolution, source of photons.
  - Tasks: Evaluate the performance with ParticleGun electrons and a control mode, $B \rightarrow K^{*} J/\psi(\rightarrow e^{+}e^{-})$

- Modification of MC-matching for neutral clusters at analysis level
  - Beneficial information for cleanup of photon ParticleList.
  - Goal: Optimize the MC-matching criteria to capture matching-failure.
  - Tasks: Investigate sources of mcPDG=NaN photons and optimize thresholds.

Service tasks for FEI

- Validate the MC used for FEI training
  - Can benefit all tools that are trained on MC
  - Goal: Check that the relevant decay model and training features are correct
  - Target: 2024 summer and beyond

- Participate in the calibration efforts of FEI
  - Used in a wide range of analyses by (S)L and EWP groups
  - Goal: Evaluate the mode-dependent calibration factors
  - Target: 2024 summer and beyond
  - Tasks:
    - Check for any signal-side dependance.
    - Measure efficiency and purity as a function of sigProb also.

- Review FEI skim selection
  - This could be impacting low-multiplicity modes like $B \to K\nu\nu$
  - Goal: Evaluate the impact of the selection on the performance
  - Tasks:
    - Measure the impact of the FEI skim selection on the efficiency.
    - Check for any signal-side dependance.

A word of caution

- The lists I presented are by no means exhaustive;
- Sometimes emergencies pop up, people leave with short notice, … ;
- Sometimes people (e.g. you guys) have brilliant ideas that we never considered before;
- Other times we might even not be aware of specific needs from the analysis groups. Please come talk to us, we are more than happy to discuss things with you, and we can recognize your contributions as service tasks, as long as they are useful to other people in the Collaboration;
- And as always: do not assume that things will happen automatically and just in time for the approval of your paper.

Conclusions

- Physics Performance, like all other areas of the experiment, relies of the dedication and skill of many Belle II members;
- We need also your help!
- There are many important service tasks and you do not need to be a super expert to make useful contributions (but we promise that you will learn!);
- I do not expect that this talk will clarify everything about potential service tasks and I anticipate that I will not be able to answer all your questions. This is meant for you to start thinking about it. Please discuss with your supervisor, senior colleagues, friends;
- And more importantly...

Talk to us!

Coordinators: Angelo Di Canto, Petar Rados

Group	**Conveners**
Charged PID	Ale Gaz, Stefan Wallner
Neutrals	Eldar Ganiev, Daniel Pitzl
Tracking and vertexing	Giulia Casarosa, Thomas Lueck
Trigger and event properties	Marcello Campajola, Radek Zlebcik
Analysis Tools	Yo Sato, Vidya Vobbilisetti

(in case we have not spammed your mail box yet,
you can easily find our e-mail addresses using B2MMS)

Backup Slides

Details on Tracking service tasks:

SYSTEMATICS	description	desired skills	priority
K^0-K^0bar	• estimate effect of the different interaction with the material of K0 and K0bar	• analysis skills	medium
charge detection asymmetry	• measure the detection asymmetry of positive and negative tracks in bins of (p_T,cosθ)	• analysis skills	high
tracking efficiency with partial reconstruction of D*-tagged $D^0 \rightarrow K3\pi$	• momentum range overlaps with tau-method, but provides a good probe-track momentum estimation	• analysis skills	medium
tracking efficiency with e+e-→πππππγ	• advantage the missing momentum can be reconstructed, see https://arxiv.org/abs/1207.2849	• analysis skills	low

Details on Tracking service tasks:

PERFORMANCE	description	desired skills	priority
PXD hit attachment efficiency	• lower than expected, why?	• some c++ needed but also analysis	medium
SVD & CDC finding relative efficiency	• what is the efficiency of the CDC finding a track found by SVD? • and vice-versa?	• some c++ needed but also analysis	high

Details on Tracking service tasks:

SOFTWARE	description	desired skills	priority
performance of an inside-out tracking chain	• revert the tracking chain starting from SVD and then do CDC, and evaluate detailed performance	• analysis skills	high
code optimization	• run analytic tools (e.g. valgrind) to find inefficient (run time) parts of the code • try to improve these code parts	• interest in c++ • existing c++ skills are advantageous	medium
retraining of CKF and other MVA filters	• retrain existing MVA filter to improve bkg rejection	• analysis skills	medium
improvement of the toCDC CKF	• improve the attaching of CDC hits to SVD tracks	• c++ required	low
Investigate usage of ACTS	• ACTS is a common tracking software developed by someone • first step implementation of the Belle II geometry in ACTS	• track fitting • c++	low