#### WP1 status (Belle II software and physics case)

Christoph Schwanda (HEPHY) JENNIFER Consortium General Meeting KEK, October 6, 2017



#### SuperKEKB

# Belle II upgrade

- 2011-2018: major upgrade of both the collider and the detector (Belle → Belle II, KEKB → SuperKEKB)
- Physics data taking starts late 2018/early 2019
- Aim to increase the Belle data set by a factor of 50











Big Questions: Are determinations of angles consistent with determinations of the sides of the triangle ? Are angle determinations from loop and tree decays consistent ?







#### Will CKM unitarity hold at Belle II?



The angle γ/φ<sub>3</sub> A fierce competion between Belle II and LHCb



#### Rare decays, charm physics,

Observable	Expected th.	Expected exp. Facility		
	accuracy	uncertainty		
CKM matrix				
$ V_{us}  [K \rightarrow \pi \ell \nu]$	**	0.1%	K-factory	
$ V_{cb}  [B \rightarrow X_c \ell \nu]$	**	1%	Belle II	
$ V_{ub}  [B_d \rightarrow \pi \ell \nu]$	*	4%	Belle II	
$\sin(2\phi_1) [c\bar{c}K_S^0]$	***	$8 \cdot 10^{-3}$	Belle II/LHCb	
$\phi_2$		1.5°	Belle II	
$\phi_3$	***	3°	LHCb	
CPV				
$S(B_s \rightarrow \psi \phi)$	**	0.01	LHCb	
$S(B_s  o \phi \phi)$	**	0.05	LHCb	
$S(B_d \rightarrow \phi K)$	***	0.05	Belle II/LHCb	
$S(B_d \rightarrow \eta' K)$	***	0.02	Belle II	
$S(B_d \to K^*(\to K^0_S \pi^0)\gamma))$	***	0.03	Belle II	
$S(B_s  o \phi \gamma))$	***	0.05	LHCb	
$S(B_d \rightarrow \rho \gamma))$		0.15	Belle II	
$A_{SL}^d$	***	0.001	LHCb	
$A_{SL}^s$	***	0.001	LHCb	
$A_{CP}(B_d \rightarrow s\gamma)$	*	0.005	Belle II	
rare decays				
$\mathcal{B}(B \to \tau \nu)$	**	3%	Belle II	
$B(B \rightarrow D\tau\nu)$		3%	Belle II	
$\mathcal{B}(B_d \rightarrow \mu\nu)$	**	6%	Belle II	
${\cal B}(B_s  o \mu \mu)$	***	10%	LHCb	
zero of $A_{FB}(B \rightarrow K^* \mu \mu)$	**	0.05	LHCb	
$\mathcal{B}(B \rightarrow K^{(*)}\nu\nu)$	***	30%	Belle II	
$\mathcal{B}(B \rightarrow s\gamma)$		4%	Belle II	
$\mathcal{B}(B_s \rightarrow \gamma \gamma)$		$0.25 \cdot 10^{-6}$	Belle II (with 5 ab <sup>-1</sup> )	
$B(K \rightarrow \pi \nu \nu)$	**	10%	K-factory	
$\mathcal{B}(K \to e \pi \nu) / \mathcal{B}(K \to \mu \pi \nu)$	***	0.1%	K-factory	
charm and $\tau$				
$\mathcal{B}(\tau \rightarrow \mu \gamma)$	***	$3 \cdot 10^{-9}$	Belle II	
$ q/p _D$	***	0.03	Belle II	
$arg(q/p)_D$	***	$1.5^{\circ}$	Belle II	







### Tau lepton flavour violation



EU grant n.644294

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#### Searching for dark matter

**SM** 

SM



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**Direct detection** 



**Direct production @ colliders** 





Search for events with missing energy, particle disappearance, dark forces, etc.

Search for interaction of DM particles with (usually) underground detectors: heat, scintillation light, etc..

Space/earth based experiments: gamma ray energy excess, anti-particle excess, HE neutrinos etc.



**Indirect detection** 





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#### Quarkonium

#### Quarkonium-like states



#### Belle II collaboration map



 104 Belle II institutions in 24 countries: WP1 typically uses secondments for attending collaboration meetings/workshops at KEK







### **Objectives of WP1**

Exploit the physics potential of Belle II by

- Task 1.1: Developing the detector-related software (charged track reconstruction, alignment, particle identification, ...)
- Task 1.2: Implementing software tools for physics analysis
- Task 1.3: Identify the key measurements for Belle II (Belle II-theory interface platform)







### Performance neutral & e<sup>-</sup> (MC9)



- ECL resolution (Energy (a) and θ (b)) & efficiency (c).
- Electron ID E/p (d). Plan to use add more ECL shower variables. Material budget in front of ECL (e)
- K<sub>L</sub> ID in KLM. (f)
- MC9 (Release & Bkg conditions) Performance note in preparation (Phases II & III)

#### Performance Hadron ID & Tracking (MC9)



- $pr/\pi ID: \Lambda \rightarrow p\pi$  (d). Discovered Pythia lifetime config problem.
- We need to prepare coherent plan for systematics measurements (Tuesday session)

# Particle ID (MC9 ccbar)



 Degradation of global PID due to over-weighting of dE/dx in combination. This needs to be resolved. Affects other PID.

## **Vertex Fitters & Conversions**



- Tree Fitter ready (Full decay chain fit, full covariance, fits with neutrals, 3-D beam constraint) CLHEP & ROOT conversion to Eigen Library in progress. (a)
- Conversion vertex analysis: new analytical variables to identify π<sup>0</sup> decay types using RAVE. (b)

#### Background overlay

Big impact on Belle II GRID computing

- Benefits w.r.t background mixing
  - measured background (with random trigger) instead of simulated one
  - smaller background files for the same number of events (by 20 times)
  - faster simulation (by factor of four)

CPU time for generic BBbar [seconds/event]			
	background mixing background overlay		
Simulation	4.40	1.16	Ī
Tracking	1.70	1.88	
PID	0.18	0.16	
Clustering	0.11	0.11	
Total	6.40	3.34	

Implementation in basf2 almost ready (planned for release-01-00-00)

- overlay framework developed to unify the approach
- all detectors except ECL implemented (ECL code in a feature branch → under review)

M. Staric (IJS)

Much better performance but has not been implemented in MC9 because of the storage issue

#### **Current Performance of the VXDTF2**

	Finding Eff.	Fake Rate	Clone Rate	Runtime / Event
VXDTF1	84.04	18.07	0.41	32.7 ms
VXDTF2	93.58	20.62	0.43	16.3 ms

1.00 0.95 Finding efficiency 0.75 84.04 - VXDTF1 93.58 - VXDTF2 0.70 0.51.0 1.5 2.02.5 0.0Transverse momentum / GeV

SVD stand-alone tracking with the VXDTF2

Keep in mind for the fake rate:

- final fit quality can improve it
- background contains real (electron) tracks, that at low momentum maybe can be filtered with dE/dx from (interesting) hadrons
- no shape, energy or time information from the SVD used (effective integration time is large)
- Memory footprint can be reduced strongly without efficiency loss (not yet committed)

#### **Combinatorial Kalman Filter Studies Progressing well**

	VXDTF2	CKF <sup>2</sup>
Finding Ef.	0.933	0.947
Hit Ef. (SVD)	0.782	0.912
Hit Ef. (PXD)	0.812	0.857
Fake Rate	0.178	0.138
Clone Rate	0.091	0.064
Hit Purity (PXD)	0.858	0.916

CKF<sup>2</sup>:

#### "Afterburner"

- CDC stand-alone tracking
- Extrapolation to SVD with CKF
  - Take out assigned hits
- SVD stand-alone tracking
- Merge CDC and SVD tracks
- Extrapolation to PXD with CKF

Performance measure vs MC Tracks

VXDTF2 details may differ from previous page due to sector map

# B2TiP

- The "Belle II Theory Interface Platform" is a joint theory-experiment effort to define the Belle II physics program
- B2TiP is organized in 9 working groups
- The charge of each WG is to identify the "golden modes", perform simulation studies and finally produce a chapter of the B2TiP report
- The activity is driven by a series of workshops







#### B2TiP WG structure

WG1	Semileptonic & Leptonic B decays
WG2	Radiative & electroweak penguins
WG3	$lpha$ ( $\phi_2$ ) and $eta$ ( $\phi_1$ )
WG4	$\phi_3$
WG5	Charmless hadronic B decays
WG6	Charm physics
WG7	Quarkonium-like states
WG8	Tau, low multiplicity and electroweak physics
WG9	New Physics (models)







### B2TiP workshop series

- 1. October 30-31, 2014 @ KEK
- 2. April 27-29, 2015 @ Krakow
- 3. October 28-29, 2015 @ KEK\*)
- 4. May 23-25, 2016 @ Pittsburgh\*)
- 5. November 15-17, 2016 @ MIAPP Munich (editorial meeting)

plus the kickoff meeting June 16-17, 2014 @ KEK and a few focused meetings

\*) co-funded by JENNIFER



#### Status of Belle II Physics Book

- Belle II physics book (630p), to be printed by PTEP / Oxford University Press <u>https://confluence.desy.de/display/BI/B2TiP+ReportStatus</u>
- A few small unfinished areas, but otherwise close to complete and ready for review to commence.
- Await formation of Belle II publication committee to conduct collaboration wide review and form full collaboration author list ASAP.



P. Urquijo et al.



### WP1 secondments

Period 1 (months 1-24)
– Total performed: 13.6 months

	INFN	НЕРНҮ	IFJ PAN	UKP	JSI	METU	CNRS
Seconded days	178	31	78	64	26	0	30

- Period 2 (months 25-48)
  - Performed so far: 171 days (5.7 months)
  - Planned for period 2: 52.8 months
  - 47.1 months are thus still open



# WP1 deliverables

- D1.1 Offline workshop
  - Description: Annual workshops amongst participants to discuss the status of offline software, outstanding issues and possible improvements, and to exchange knowledge amongst involved researchers
  - Due: March 2016
  - Delivered: September 2016
- D1.2 Belle II tutorials
  - Description: Tutorial courses for Belle II members (especially ESRs) attached to Belle II collaboration meetings, to demonstrate the use of physics analysis tools
  - Due: March 2016
  - Delivered: September 2016



# WP1 deliverables

- D1.3 Reference guide
  - Description: Writing and maintaining a reference data reconstruction and analysis tools guide
  - Due: March 2018
  - Delivered: pending
- D1.4 B2TiP report
  - Description: "Belle II Yellow Report" summarizing all important observables and including a "milestone table", clarifying the targets for the first 5/ab, 10/ab as well as for the final goal at 50/ab
  - Due: March 2017
  - Delivered: May 2017



# Summary

- The Belle II experiment has a rich physics case and will study decays of B and charmed mesons and tau leptons from 2019
- WP1 is helping the exploitation of Belle II physics through supporting offline-software development, implementation of analysis tools and the B2TiP activity
- 13.6 WP1 secondment months in period 1, 5.7 months done in period 2, 47.1 months to go
- No problems foreseen in the preparation of the remaining deliverable

