Computing Resources

. During the last B2GM/BGM, Thomas, Tom and I discussed

. We estimated the required CPU, Storage, Network and budget for Tier-0 and Tier-1 centers

. 3 scenarios are considered

Low : Assumes bad accelerator performance, low background level, low event size, etc...

Baseline : Our best guess of accelerator performance, background level, event size, etc...

High : Assumes good accelerator performance, high background level, high event size, etc...

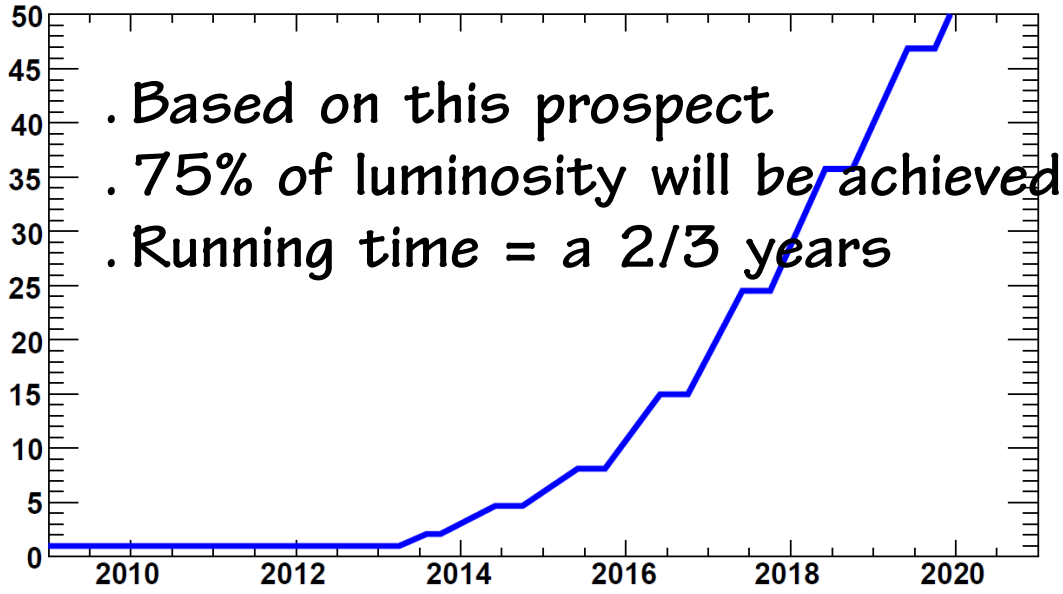
The computing system for Belle II will be delivered in 2012 Feb.-Mar.
Four years later, the system will be upgraded, i.e. during 2015 FY.
So, to establish the practical computing design satisfying the requirement in 2015 is very important, now.

Event rate

. Cross section [nb]

BBbar	1
udsc	3
tau	1
2 photon	3
Background	16
Sum (all)	24

. Luminosity



. Number of events (integrated)

Year	2013	2014	2015	2016
BBbar	3.12E+09	7.58E+09	1.34E+10	2.05E+10
Physics	2.50E+10	6.07E+10	1.07E+11	1.64E+11
All	7.49E+10	1.82E+11	3.21E+11	4.92E+11
Trigger [kHz]	3.60	5.15	6.69	8.22

Storage

. Raw data size [kB/ev]

PXD	???
SVD	8
CDC	18
TOP	1-6
ARICH	4-7
ECL	12
KLM	2-4
TRG	10
Total	55-65

. At this moment, total raw data size is assumed to be 150kB/event

. In Belle-II computing design, all raw data is required to be stored in Tier-0

. Raw data size is very critical for Belle-II computing design

— possible solution, but not sure... —
. reduce the information (only hit pattern) ?
. compress the data ?
. discard the entire/only PXD raw data ?

. Required Storage size (raw data size = 150kB/ev is assumed)

~1.5 MB/ev

Year	2013	2014	2015	2016
Size per year [PB]	10.22	14.61	18.98	23.35
Total size [PB]	10.22	24.83	43.81	67.16

~440 PB

~$62M
($140/TB)

Comparison

Experiment	HLT rate [kHz]	Raw event size [kB]
ALICE (HI)	0.10	12,500
ALICE (pp)	0.10	1,000
ATLAS	0.20	1,600
CMS	0.15	1,500
LHCb	2.00	25
CDF	???	150
Belle	0.4	30
BaBar	0.36[level 3]	35
Italian B	25 [level 3]??	75
Belle-II	3.6	????? (150?, 1,500?)
Belle-II(@2015)	6.7	?????

The following color coding is used in this table:							
green backgroud	is used for input values						
For the calculations in this table we assume three different scenarios of low, baseline, and high resource requirements:							
Scenario	**Description**						
low	Assumes bad accelerator performance, low background level, low event size, etc.						
baseline	Our best guess of accelerator performance, background level, event size, etc.						
high	Assumes good accelerator performance, high background, high event size, etc.						
default	Used on the following sheets if the scenario there is the one selected on this sheet						
The selected scenario is:	baseline						

Scenario	default	baseline			
Raw data:	*The numbers are maily based on Nishida-san's survey*				
Scenario	**low**	**baseline**	**high**	**used**	
Detector	**event data size [kB]**				**Remark**
PXD	0		400		400 is above DAQ limit
SVD	8		8		Could be below 8
CDC	18		36		
TOP	1		6		
ARICH	4		7		
ECL	12		24		
KLM	2		4		
TRG	0		10		No serious estimate yet
Sum	45	150	495	**150**	
For comparison:					
Belle	30				
DST and mDST data:					
Scenario	**low**	**baseline**	**high**	**used**	
Data type	**event data size [kB]**				**Remark**
DST	140	200	600	**200**	Used for calibration, @Belle ~140
mDST (data)	30	30	40	**30**	Current Belle event size is ~30
mDST (MC)	30	30	40	**30**	Same as for data is assumed

Scenario	default	baseline										
Cross sections:												
Scenario	low	baseline	high	used								
Process	cross section [nb]											
BBbar	1	1	1	1								
udsc	3	3	3	3								
tau	1	1	1	1								
2 photon	0	3	3	3								
Background	10	16	25	16								
Sum (hadronic)	4	4	4	**4**								
Sum (physics)	5	8	8	**8**								
Sum (all)	15	24	33	**24**								
Data taking time per year:												
Scenario	low	baseline	high	used								
Year [s]		3.15E+07										
Running factor	0.66	0.66	0.66	0.66								
Effective [s]	2.08E+07	2.08E+07	2.08E+07	**2.08E+07**	*Seconds per year times running time scale factor*							
Accelerator performance:												
Scenario	low	baseline	high	used								
Luminosity factor	0.5	0.75	1	**0.75**								
Luminosity:												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Projected L_int/year [1/ab]	0.00	0.00	0.00	4.16	5.95	7.73	9.51	11.30	13.08	14.87	16.65	*The projected annual integrated luminosity is determined from a Super-KEKB luminosity projection plot.*
Assumed L_int/year [1/ab]	0.00	0.00	0.00	3.12	4.46	5.80	7.13	8.48	9.81	11.15	12.49	*The assumed annual integrated luminosity is determined from the projected one times luminosity factor.*
Assumed total L_int [1/ab]	0.00	0.00	0.00	3.12	7.58	13.38	20.51	28.99	38.80	49.95	62.44	*Sum of the annual values*
Events:												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
BBbar												
per year	0.00E+00	0.00E+00	0.00E+00	3.12E+09	4.46E+09	5.80E+09	7.13E+09	8.48E+09	9.81E+09	1.12E+10	1.25E+10	*BBbar cross section times assumed annual luminosity*
integrated	0.00E+00	0.00E+00	0.00E+00	3.12E+09	7.58E+09	1.34E+10	2.05E+10	2.90E+10	3.88E+10	5.00E+10	6.24E+10	*Sum of the annual values*
Hadronic												
per year	0.00E+00	0.00E+00	0.00E+00	1.25E+10	1.79E+10	2.32E+10	2.85E+10	3.39E+10	3.92E+10	4.46E+10	5.00E+10	*BBbar + udsc cross section times assumed annual luminosity*
integrated	0.00E+00	0.00E+00	0.00E+00	1.25E+10	3.03E+10	5.35E+10	8.21E+10	1.16E+11	1.55E+11	2.00E+11	2.50E+11	*Sum of the annual values*
Physics												
per year	0.00E+00	0.00E+00	0.00E+00	2.50E+10	3.57E+10	4.64E+10	5.71E+10	6.78E+10	7.85E+10	8.92E+10	9.99E+10	*Physics cross section times assumed annual luminosity*
integrated	0.00E+00	0.00E+00	0.00E+00	2.50E+10	6.07E+10	1.07E+11	1.64E+11	2.32E+11	3.10E+11	4.00E+11	5.00E+11	*Sum of the annual values*
All												
per year	0.00E+00	0.00E+00	0.00E+00	7.49E+10	1.07E+11	1.39E+11	1.71E+11	2.03E+11	2.35E+11	2.68E+11	3.00E+11	*Total cross section times assumed annual luminosity*
integrated	0.00E+00	0.00E+00	0.00E+00	7.49E+10	1.82E+11	3.21E+11	4.92E+11	6.96E+11	9.31E+11	1.20E+12	1.50E+12	*Sum of the annual values*
L3 Rates:												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Trigger [kHz]	0.00	0.00	0.00	3.60	5.15	6.69	8.22	9.77	11.31	12.86	14.40	*Number of total events divided by effective seconds per year*
DAQ [MB/s]	0	0	0	540	772	1,003	1,234	1,466	1,697	1,929	2,160	*Trigger rate times raw event size*
For comparison:												
DAQ output rate assumed by Itoh-san is 300 MB/s without PXD at low luminosity.												
See also DAQ rates of other experiments on "Comparison" sheet.												

Scenario	default	baseline										
Event processing resources:												
Scenario	low	baseline	high	used								
Measurement [HepSPEC*s/ev]		5.55			*The measured event processing resource requirements can be found in the twiki.*							
Scale factor	1	1.5	2	1.5								
Resources [HepSPEC*s/ev]	5.55	8.33	11.10	**8.33**	*Measured resources times scale factor for Belle II compared to Belle*							
Production time period per year:												
Scenario	low	baseline	high	used								
Time [months]	8	5	3	5								
Time [s]	2.10E+07	1.31E+07	7.88E+06	**1.31E+07**								
DST event output fraction:												
Scenario	low	baseline	high	used								
Time [months]	0.01	0.02	0.03	**0.02**								
Raw data:												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Size per year [PB]	0.00	0.00	0.00	10.22	14.61	18.98	23.35	27.75	32.12	36.52	40.89	*Raw data event size times total number of events*
Total size [PB]	0.00	0.00	0.00	10.22	24.83	43.81	67.16	94.91	127.03	163.55	204.43	*Sum of the annual values*
CPU [kHepSPEC]	0.00	0.00	0.00	47.44	67.85	88.15	108.45	128.87	149.17	169.58	189.88	*Event processing resources divided by number of seconds for production multiplied by total number of events*
mDST:												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Size per year [PB]	0.00	0.00	0.00	0.68	0.97	1.27	1.56	1.85	2.14	2.43	2.73	*mDST event size times number of physics events*
Total size [PB]	0.00	0.00	0.00	0.68	1.66	2.92	4.48	6.33	8.47	10.90	13.63	*Sum of the annual values*
DST:												
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Size per year [PB]	0.00	0.00	0.00	0.27	0.39	0.51	0.62	0.74	0.86	0.97	1.09	*DST event size times total number of events times fraction of DST output events*
Total size [PB]	0.00	0.00	0.00	0.27	0.66	1.17	1.79	2.53	3.39	4.36	5.45	*Sum of the annual values*

Scenario	default	baseline															
Factor compared to data (no. of streams):																	
Scenario	low	baseline	high	used	[BBbar]	*The last column shows the number of MC events per BBbar event in data*											
BBbar	3	6	10	6	6												
udsc	3	6	10	6	18												
tau	0	0	0	0	0												
2 photon	0	0	0	0	0												
Sum					**24**												
Event processing resources:																	
Scenario	low	baseline	high	used													
Measurement [HepSPEC*s/ev]		10.96			*The measured event processing resource requirements can be found in the twiki.*												
Scale factor	1	1.5	2	1.5													
Resources [HepSPEC*s/ev]	10.96	16.44	21.92	**16.44**	*Measured resources times scale factor for Belle II compared to Belle*												
Production time period per year:																	
Scenario	low	baseline	high	used													
Time [months]	8	5	3	5													
Time [s]	2.10E+07	1.31E+07	7.88E+06	**1.31E+07**													
MC data:																	
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020						
Events per year	0.00E+00	0.00E+00	0.00E+00	7.49E+10	1.07E+11	1.39E+11	1.71E+11	2.03E+11	2.35E+11	2.68E+11	3.00E+11	*Number of BBbar events in data times stream factor per BBbar event*					
Total events	0.00E+00	0.00E+00	0.00E+00	7.49E+10	1.82E+11	3.21E+11	4.92E+11	6.96E+11	9.31E+11	1.20E+12	1.50E+12	*Sum of the annual values*					
Size per year [PB]	0.00	0.00	0.00	2.04	2.92	3.80	4.67	5.55	6.42	7.30	8.18	*MC mDST event size times number of MC events*					
Total size [PB]	0.00	0.00	0.00	2.04	4.97	8.76	13.43	18.98	25.41	32.71	40.89	*Sum of the annual values*					
CPU [kHepSPEC]	0.00	0.00	0.00	93.69	134.00	174.08	214.17	254.48	294.57	334.88	374.97	*Event processing resources divided by number of seconds for production multiplied by number of MC events*					

Scenario	default	baseline																
Fraction of resources for user analysis compared to resources for data:																		
Scenario	**low**	**baseline**	**high**	**used**														
Storage [mDST size]	0.05	0.1	0.15	0.1	For comparison: At Belle about 100 TB are used for analysis													
CPU [data prod. res.]	0.3	0.5	1	0.5	For comparison: At Belle the CPU resources are used roughly equally for data processing, MC production, and analysis													
Analysis:																		
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**							
Size per year [PB]	0.00	0.00	0.00	0.07	0.10	0.13	0.16	0.18	0.21	0.24	0.27	*Annual mDST size times fraction for analysis*						
Total size [PB]	0.00	0.00	0.00	0.07	0.17	0.29	0.45	0.63	0.85	1.09	1.36	*Sum of the annual values*						
CPU [kHepSPEC]	0.00	0.00	0.00	23.72	33.93	44.08	54.23	64.43	74.58	84.79	94.94	*Raw data processing resources times fraction for analysis*						

Scenario	default	baseline

Tier 1 contribution of KEK:

Scenario	low	baseline	high	used
Factor	0	1	2	1

Assignment of users per country to sites:

Country	No. of people	Assigned to
Australia	4	Australia
Austria	5	GridKa
Czech Rep.	5	CYFRONET
China	2	KISTI
Germany	13	GridKa
India	3	Taiwan
Italy	1	GridKa
Japan	55	KEK
Korea	11	KISTI
Poland	4	CYFRONET
Russia	8	CYFRONET
Slovenia	8	CYFRONET
Switzerland	1	GridKa
Taiwan	3	Taiwan
USA	15	USA
Sum	**138**	

Site	No. of users	Fraction [%]	
Australia	4	2.90	
CYFRONET	25	18.12	
GridKa	20	14.49	
KEK	55	**39.86**	*The numbers for KEK include the Tier1 factor*
KISTI	13	9.42	
Taiwan	6	4.35	
USA	15	10.87	
Sum	**138**		

Scenario	default	baseline																	
Tier 1 fraction:	0.40	*The fraction of MC production and user analysis done at KEK*																	
Tier 0 availability:	95.00%	98.00%	99.00%																
Model parameters:																			
Scenario	**low**	**baseline**	**high**	**used**															
Fraction of MC	0	0.40	1	0.40	*What fraction of the total MC should be stored at KEK? Baseline assumes Tier1 fraction.*														
MC versions	1	2	2	2	*How many versions of MC datasets should be kept (in case of reprocessing)?*														
mDST versions	1	2	2	2	*How many versions of mDST datasets should be kept (in case of reprocessing)?*														
mDST transfers	2	4	8	4	*To how many Tier1 sites is the mDST dataset copied?*														
Tier0 resources:																			
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**								
Tape [PB]	0.00	0.00	0.00	10.22	24.83	43.81	67.16	94.91	127.03	163.55	204.43	*Assumption: all raw data goes to tape, but nothing else.*							
Disk [PB]	0.00	0.00	0.00	3.29	8.00	14.11	21.63	30.57	40.91	52.67	65.84	*Assumption: all DST + mDST, the chosen fraction of MC, and the Tier1 fraction of analysis data go to disk.*							
CPU [kHepSPEC]	0.00	0.00	0.00	56.89	81.38	105.72	130.07	154.55	178.89	203.37	227.72	*Assumption: data processing + user analysis times Tier1 fraction. MC production and reprocessing are done during periods of no data processing.*							
WAN (in) [Gbit/s]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Assumption: the MC produced off-site and stored at KEK is imported in the same time period it is produced.*							
WAN (out) [Gbit/s]	0.00	0.00	0.00	1.74	2.49	3.23	3.98	4.72	5.47	6.22	6.96	*Assumption: the mDST data is exported to N sites in the same time period it is produced.*							

Site	GridKa																		
Tier 1 fraction:	0.14																		
Tier 1 availability:	95.00%	98.00%	99.00%																
Resource fractions:		*If a custom value is given it is used instead of the default value.*																	
	default	**custom**	**used**																
mDST data	1.00		1.00	*The fraction of mDST data stored at this site. The default is a full copy.*															
MC production	0.14		0.14	*The fraction of MC production done at this site. The default is the Tier1 fraction.*															
User analysis	0.14		0.14	*The fraction of user analysis done at this site. The default is the Tier1 fraction.*															
Tier1 resources:																			
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**								
Disk [PB]	0.00	0.00	0.00	0.99	2.40	4.23	6.49	9.17	12.27	15.80	19.75	*Assumption: the chosen fraction of mDST, the produced MC, and the fraction of analysis data go to disk.*							
CPU [kHepSPEC]	0.00	0.00	0.00	17.02	24.34	31.62	38.90	46.22	53.50	60.82	68.10	*Assumption: fractions of MC production + user analysis.*							
WAN (in) [Gbit/s]	0.00	0.00	0.00	0.43	0.62	0.81	0.99	1.18	1.37	1.55	1.74	*Assumption: the fraction of mDST data is imported in the same time period it is produced.*							
WAN (out) [Gbit/s]	0.00	0.00	0.00	0.19	0.27	0.35	0.43	0.51	0.59	0.68	0.76	*Assumption: the produced MC is exported in the same time period it is produced.*							

Cost estimates per resource:		*Based on GridKa numbers. Moore's law is NOT applied in this calculation!*
Tape [$/TB]	140	*Depends on technology. KEK computing center estimate is 300 $/TB*
Disk [$/TB]	1400	
CPU [$/HepSPEC]	60	*For ~4 years*
No. of Tier1s	4	

Estimate for Tier0 based on resource requirements for 2015:

	Resources	Cost [M$]
Tape [PB]	43.81	6.13
Disk [PB]	14.11	19.75
CPU [kHepSPEC]	105.72	6.34
Sum		32.23

Estimate for sum of Tier1s based on resource requirements for 2015:

	Resources	Cost [M$]	
Disk [PB]	20.74	29.03	*mDST data times number of Tier1s + all MC data + all analysis data*
CPU [kHepSPEC]	218.16	13.09	*all MC + all analysis resources*
Sum		42.12	

Estimate for the Tier1 on the previous sheet based on resource requirements for 2015:

	Resources	Cost [M$]
Disk [PB]	4.23	5.93
CPU [kHepSPEC]	31.62	1.90
Sum		7.82

The LCG TDR (2005, http://lcg.web.cern.ch/LCG/tdr/LCG_TDR_v1_04.pdf) gives the following numbers:

Experiment	HLT rate [kHz]	Raw event size [kB]	DAQ rate [MB/s]	
ALICE (HI)	0.10	12,500	1,250.00	
ALICE (pp)	0.10	1,000	100.00	
ATLAS	0.20	1,600	320.00	
CMS	0.15	1,500	225.00	*Current rate estimate is 0.30 kHz*
LHCb	2.00	25	50.00	

In the KEK Super B Factory LOI (2004) the following number is given:

SuperKEKB			250.00	*assuming L=10^35 cm-2 s-1*

The Italian SuperB CDR (http://www.pi.infn.it/SuperB/CDR) estimates

Experiment	raw data [PB/ab^-1]			To be compared to:		
Italian SuperB	0.88			Belle II	3.60	*our calculation based on raw data event size and cross section*
				ratio	4.11	

Year	1	2	3	4	5
Lumi [ab^-1]	2	6	12	12	12
Tape [PB/year]	3.10	10.20	22.00	26.20	27.80
Disk [PB/year]	0.83	3.35	7.55	10.20	10.20
Tape (total) [PB]	3.10	13.30	35.30	61.50	89.30
Disk (total) [PB]	0.83	4.18	11.73	21.93	32.13

Some numbers for CDF (http://cdfsam-prd.fnal.gov/~sam/data_volume/summary.html):

Type of data	size [PB]	events	event size [kB]
Raw	1.39	9.58E+09	144.78
Production	1.68	1.23E+10	136.10
MC	0.73	5.30E+09	137.28
Total (w/ nt)	4.61		

CMS numbers for 2009 are:

Type of data	CPU [MHepSpec06]	disk [PB]	tape [PB]

Tier0	30	2.2	10				
sum Tier1	52	6.4	9.7				