UNIVERSITÄT BONN

Belle II

ErUM-FSP T09 Belle II

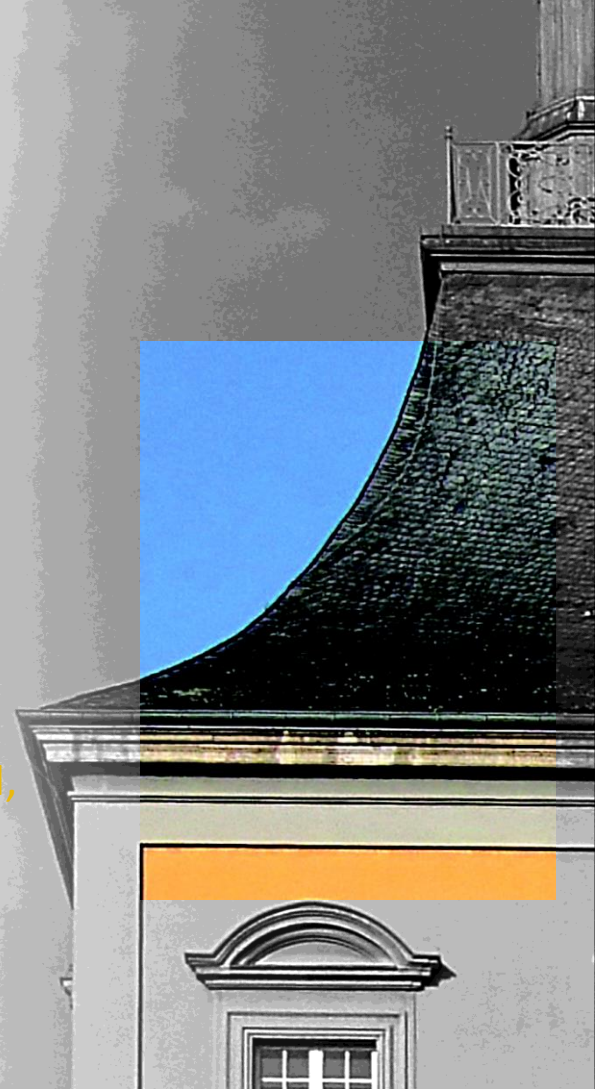
IMC STEERING MEETING:
NOV. 12, 2021

NEW MASTERCLASSES: HOW MANY COLORS DOES A QUARK COME IN?

HENRIK JUNKERKALEFELD*, SVENJA GRANDERATH, SEBASTIAN LÜLSDORF, BARBARA VALERIANI-KAMINSKI, FLORIAN BERNLOCHNER

Based on previous work of JANNIK STAMMNITZ, CHRISTIAN WESSEL, ECKHARD VON TÖRNE

* = junkerkalefeld@physik.uni-bonn.de



NEW EVENT-DISPLAY BASED MASTERCLASS

- **Goal:** (very basic) masterclass that targets a scientifically very unexperienced audience without any knowledge of particle physics (i.e. pupils)
- **Idea:** Based on event displays, classify event as $e^+e^-/\ \mu^+\mu^-/\ \tau^+\tau^-/\ \bar{q}q/\ \bar{b}b$
- Derive R-value: $R = \frac{N(\bar{q}q)}{0.5\cdot[N(\mu^+\mu^-)+N(\tau^+\tau^-)]} = N_c \cdot \sum_{\text{Quarks}} q_{\bar{q}q}^2 = N_c \cdot \frac{10}{9}$
- Deduce **number of quark colors**

➢ We developed **several materials** (ATM in German, but translation is possible)

➢ **Successfully tested** this with a group of pupil

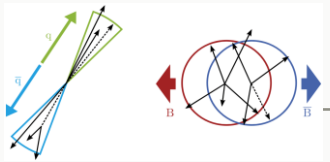
UNIVERSITÄT BONN

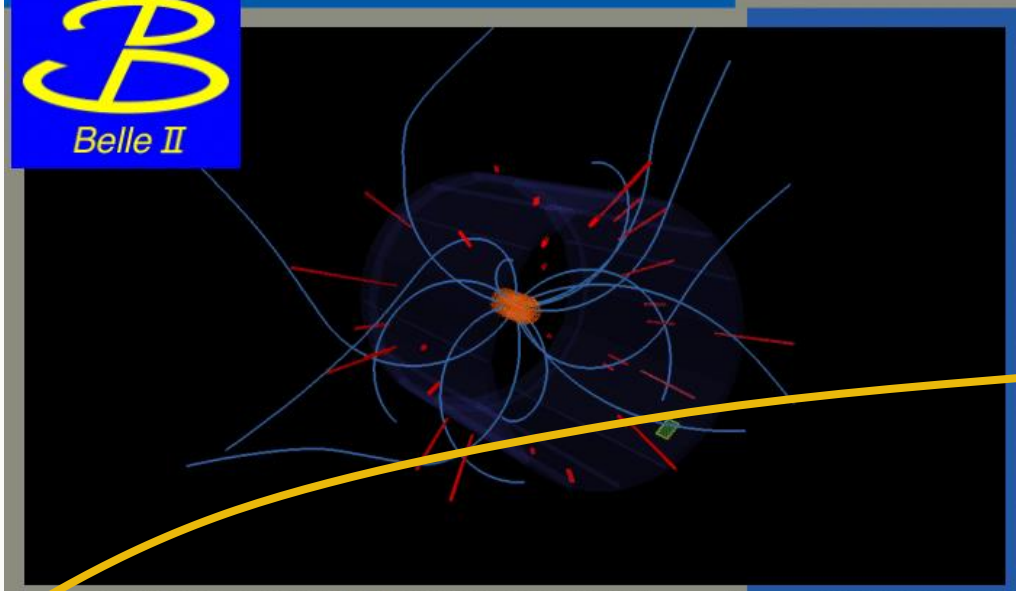
EXAMPLE EVENT DISPLAY

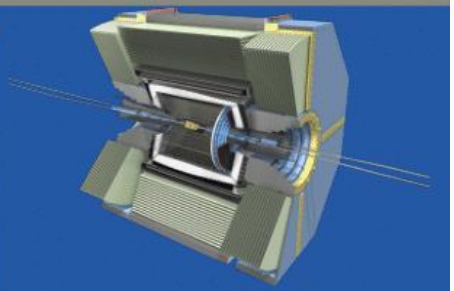
$e^+e^- \to \Upsilon(4S) \to \bar{b}b$

m^2_{miss} as "missing energy" or $\not{E}$

`foxWolframR2` as "straightness" or $\searrow$



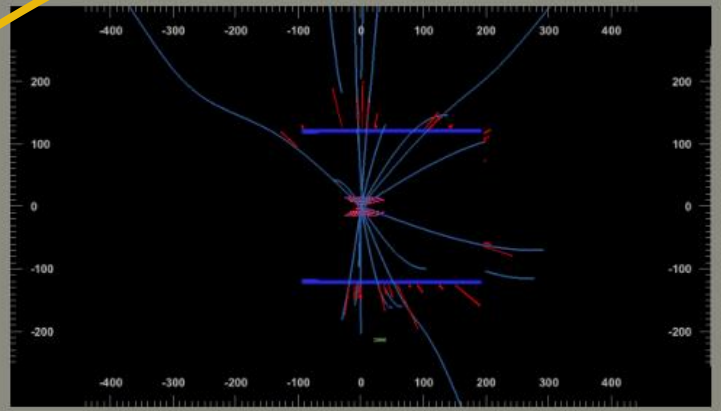


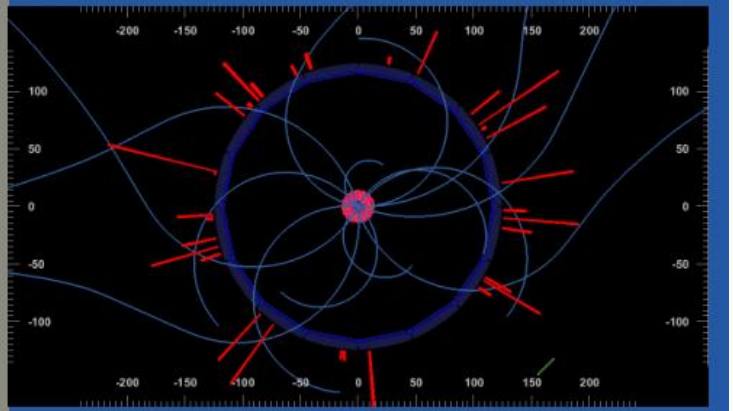


Ereignis 1

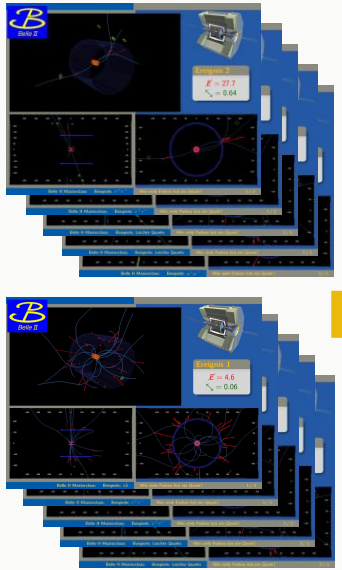
$\not{E} = 4.6$

$\searrow = 0.06$

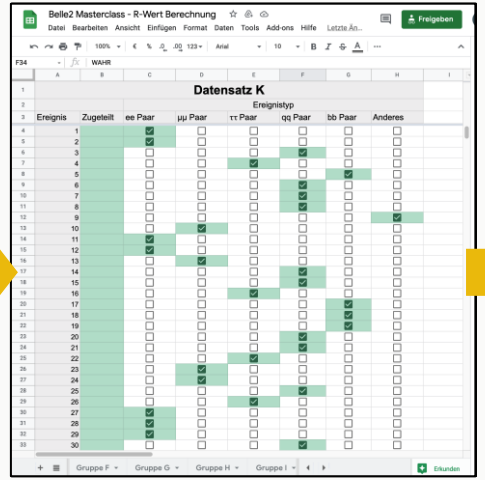




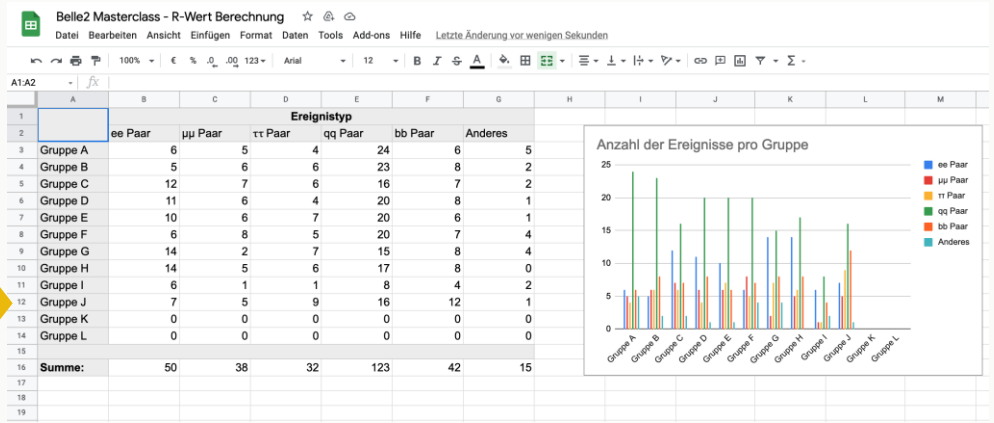
PROCESS CLASSIFICATION AND QUARK COLOR EXTRACTION



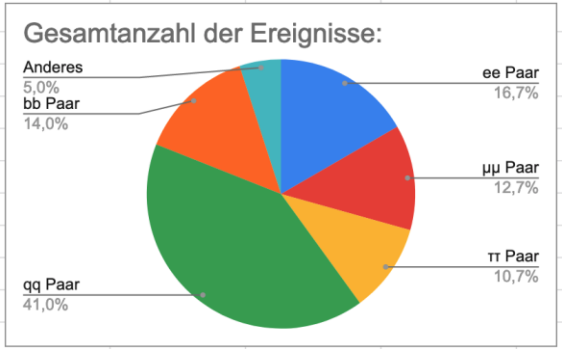
Pupils get sets of 50 – 100 events



Events are classified and filled in online



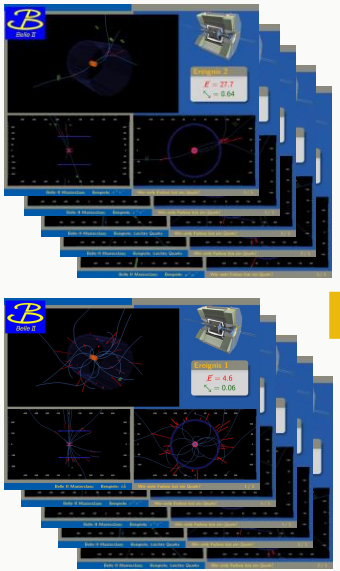
Result website:
All entries are automatically summarized and counted

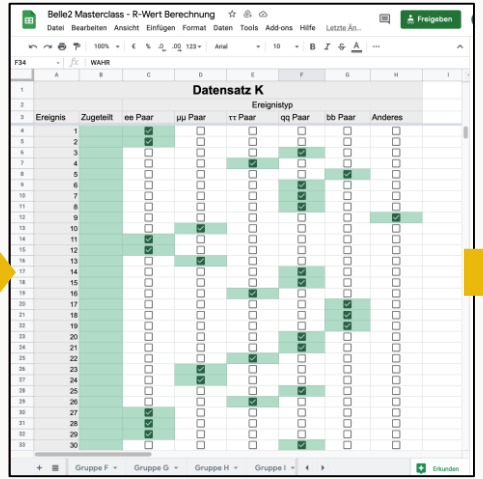


UNIVERSITÄT BONN

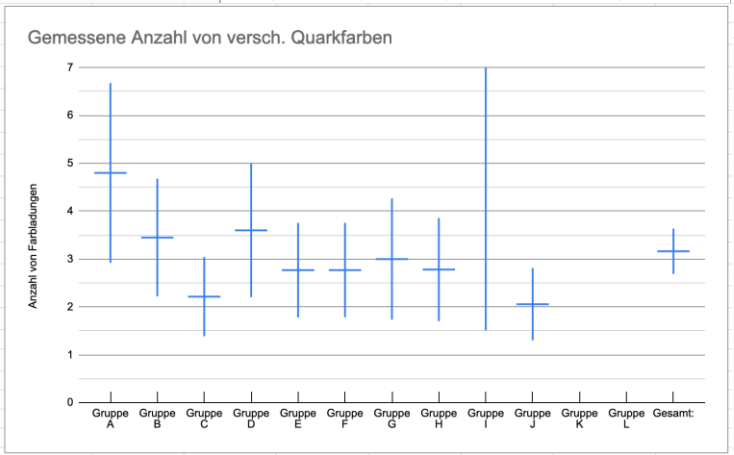
Belle II

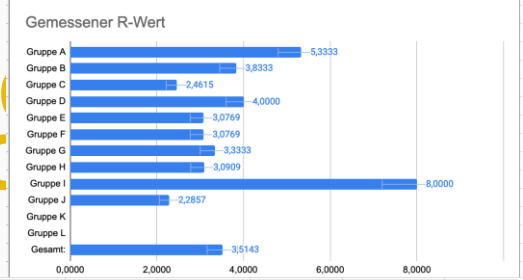
PROCESS CLASSIFICATI(QUARK COLOR EXTRAC





	Farbanzahl jeder Gruppe	Unsicherheit
Gruppe A	4,8000	1,8762
Gruppe B	3,4500	1,2286
Gruppe C	2,2154	0,8272
Gruppe D	3,6000	1,3943
Gruppe E	2,7692	0,9866
Gruppe F	2,7692	0,9866
Gruppe G	3,0000	1,2649
Gruppe H	2,7818	1,0764
Gruppe I	7,2000	5,6921
Gruppe J	2,0571	0,7528
Gruppe K	#DIV/0!	#DIV/0!
Gruppe L	#DIV/0!	#DIV/0!
Gesamt:	**3,1629**	**0,4735**



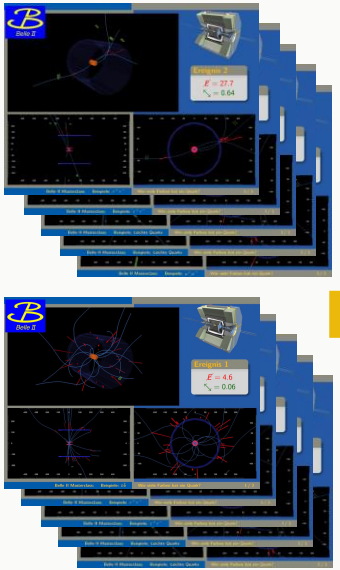


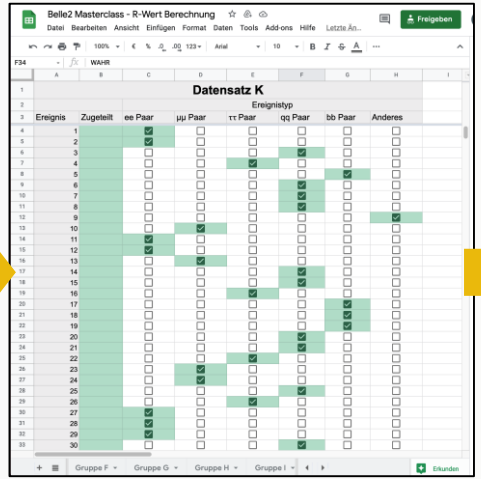
Pupils get sets of 50 – 100 events

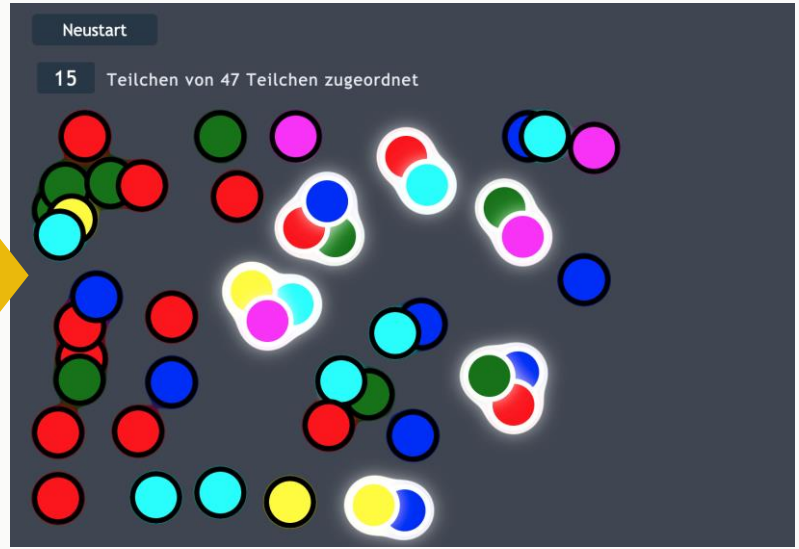
Events are classified and filled in online

Result website: The number of quark colors (derived from the R-value) is calculated for each group individually and all combined (with statistical errors)

PROCESS CLASSIFICATION AND QUARK COLOR EXTRACTION







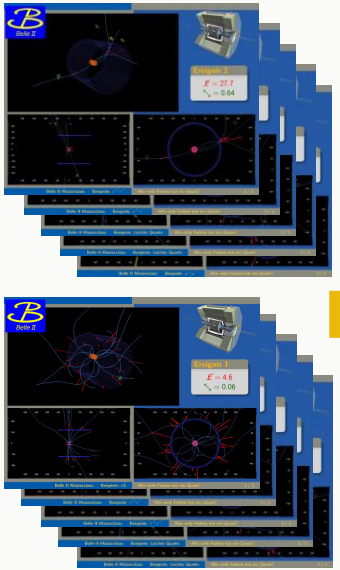
Pupils get [sets of 50 – 100 events]

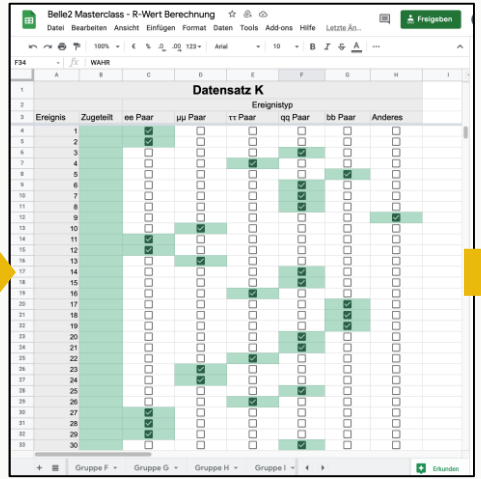
Events are classified and [filled in online]

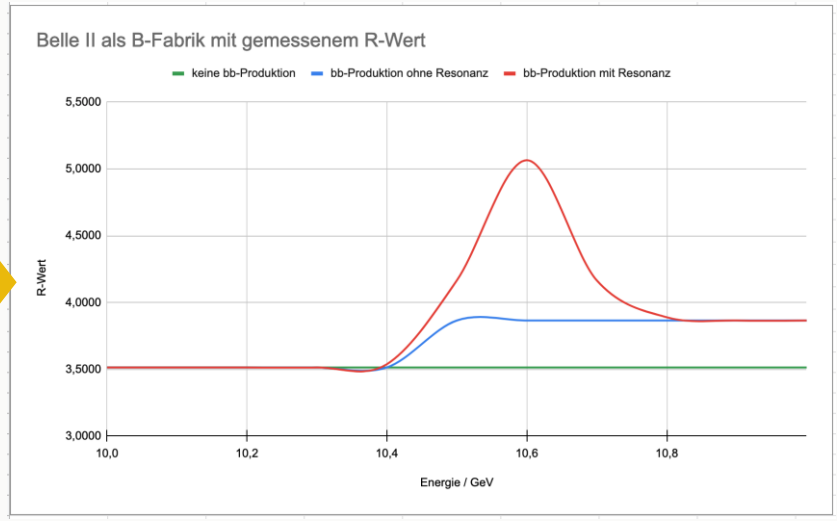
[Interactive color-combination minigame]:

Directly learn what “three colors” mean

PROCESS CLASSIFICATION AND QUARK COLOR EXTRACTION





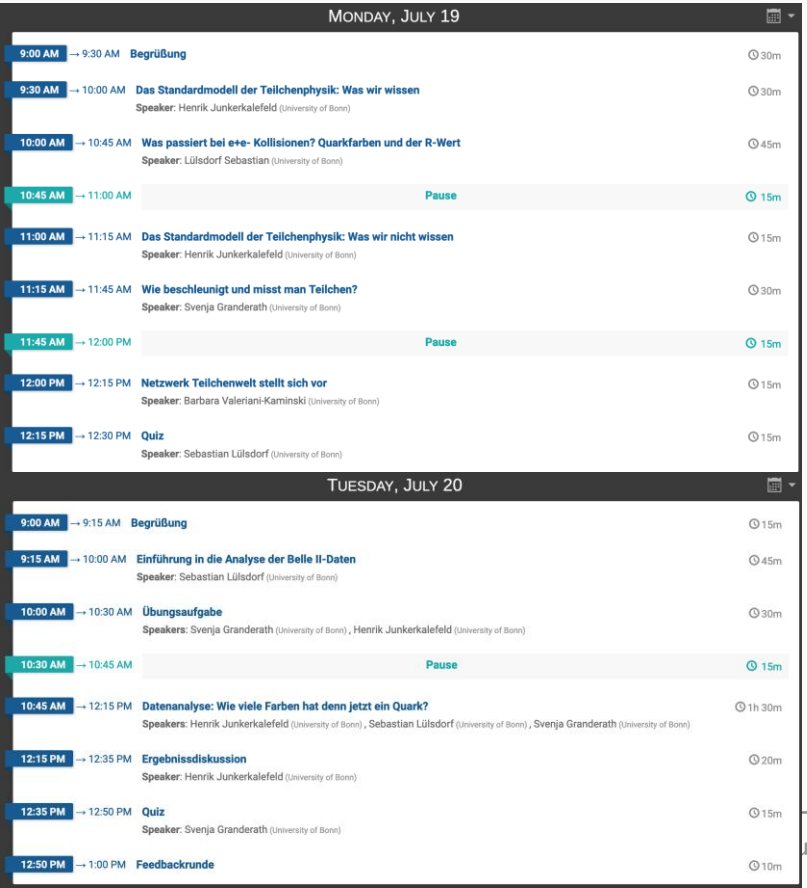


Pupils get sets of 50 – 100 events

Events are classified and filled in online

Result website: Bonus: It is shown how B mesons are produced favorably at Belle II based on event classification of pupils

MASTERCLASS SCHEDULE (INDICO) AND ADDITIONAL MATERIAL



Monday, July 19

9:00 AM → 9:30 AM	**Begrüßung**	30m
9:30 AM → 10:00 AM	**Das Standardmodell der Teilchenphysik: Was wir wissen** Speaker: Henrik Junkerkalefeld (University of Bonn)	30m
10:00 AM → 10:45 AM	**Was passiert bei e+e- Kollisionen? Quarkfarben und der R-Wert** Speaker: Lülsdorf Sebastian (University of Bonn)	45m
10:45 AM → 11:00 AM	**Pause**	15m
11:00 AM → 11:15 AM	**Das Standardmodell der Teilchenphysik: Was wir nicht wissen** Speaker: Henrik Junkerkalefeld (University of Bonn)	15m
11:15 AM → 11:45 AM	**Wie beschleunigt und misst man Teilchen?** Speaker: Svenja Granderath (University of Bonn)	30m
11:45 AM → 12:00 PM	**Pause**	15m
12:00 PM → 12:15 PM	**Netzwerk Teilchenwelt stellt sich vor** Speaker: Barbara Valeriani-Kaminski (University of Bonn)	15m
12:15 PM → 12:30 PM	**Quiz** Speaker: Sebastian Lülsdorf (University of Bonn)	15m

Tuesday, July 20

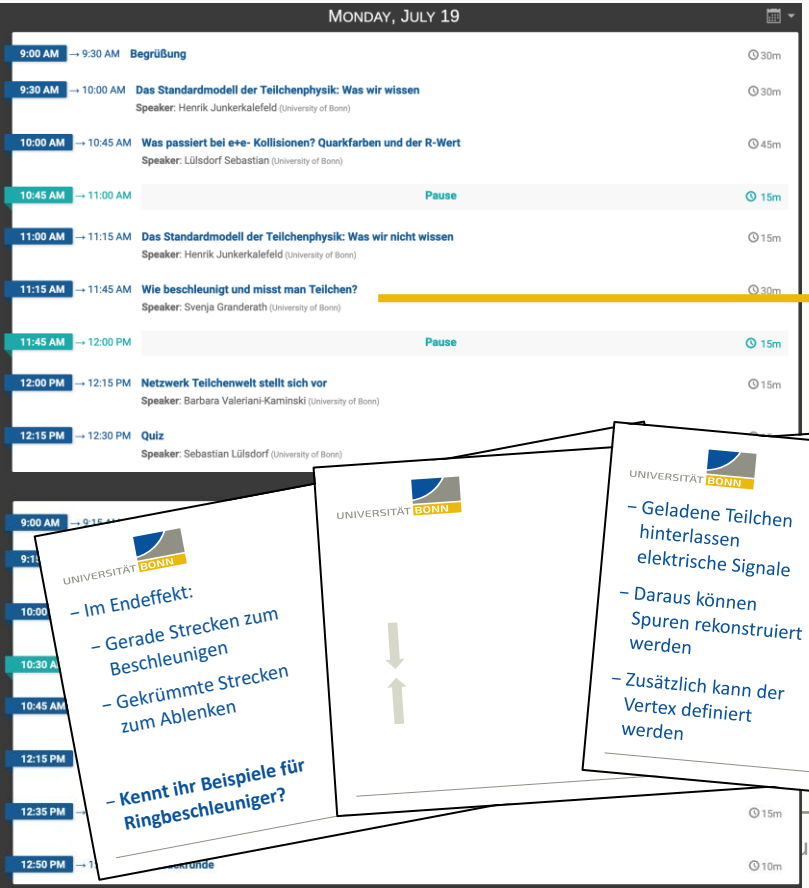
9:00 AM → 9:15 AM	**Begrüßung**	15m
9:15 AM → 10:00 AM	**Einführung in die Analyse der Belle II-Daten** Speaker: Sebastian Lülsdorf (University of Bonn)	45m
10:00 AM → 10:30 AM	**Übungsaufgabe** Speakers: Svenja Granderath (University of Bonn) , Henrik Junkerkalefeld (University of Bonn)	30m
10:30 AM → 10:45 AM	**Pause**	15m
10:45 AM → 12:15 PM	**Datenanalyse: Wie viele Farben hat denn jetzt ein Quark?** Speakers: Henrik Junkerkalefeld (University of Bonn) , Sebastian Lülsdorf (University of Bonn) , Svenja Granderath (University of Bonn)	1h 30m
12:15 PM → 12:35 PM	**Ergebnissdiskussion** Speaker: Henrik Junkerkalefeld (University of Bonn)	20m
12:35 PM → 12:50 PM	**Quiz** Speaker: Svenja Granderath (University of Bonn)	15m
12:50 PM → 1:00 PM	**Feedbackrunde**	10m

TWO INTRODUCTORY TALKS

Introductory presentation:

- Why particle physics?
- What do we know? (introduction of important particles and forces)
- How (often) are they produced?
- What is still a mystery?

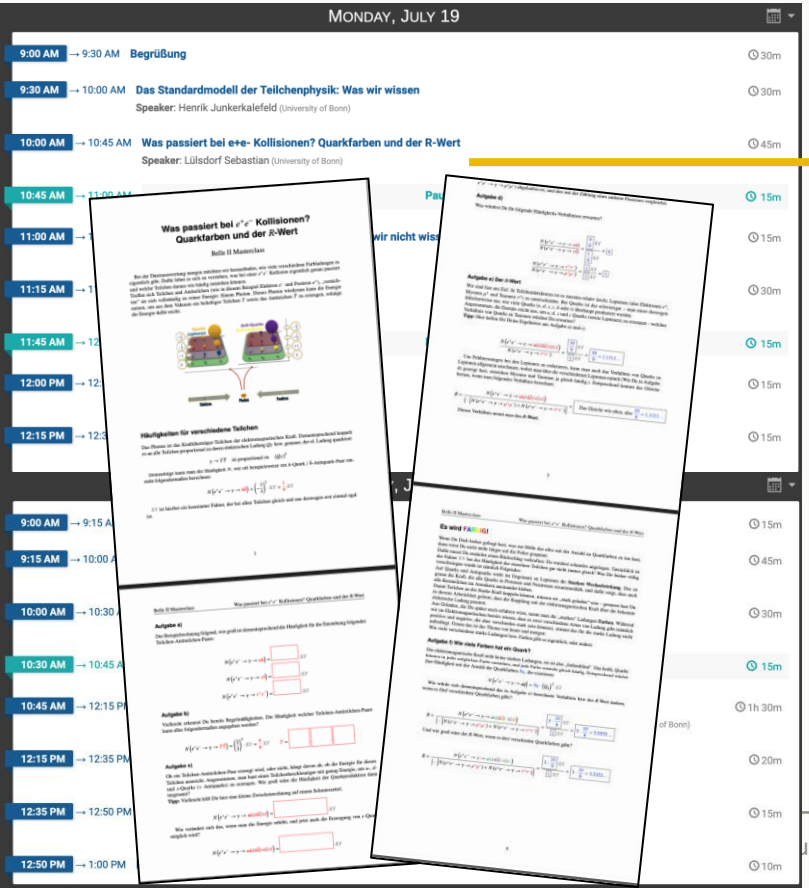
TWO INTRODUCTORY TALKS



Second presentation:

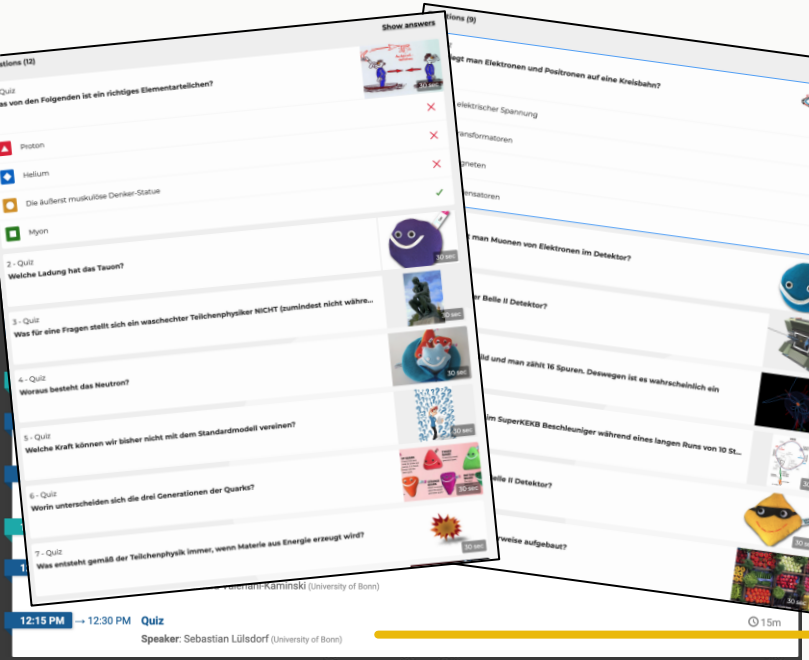
- What is a particle accelerator/collider?
- How do we measure and distinguish particles?

INTERACTIVE WORK SHEET



[Work sheet]():

- Autodidactic derivation of expected R-value and its dependence of the quark colours

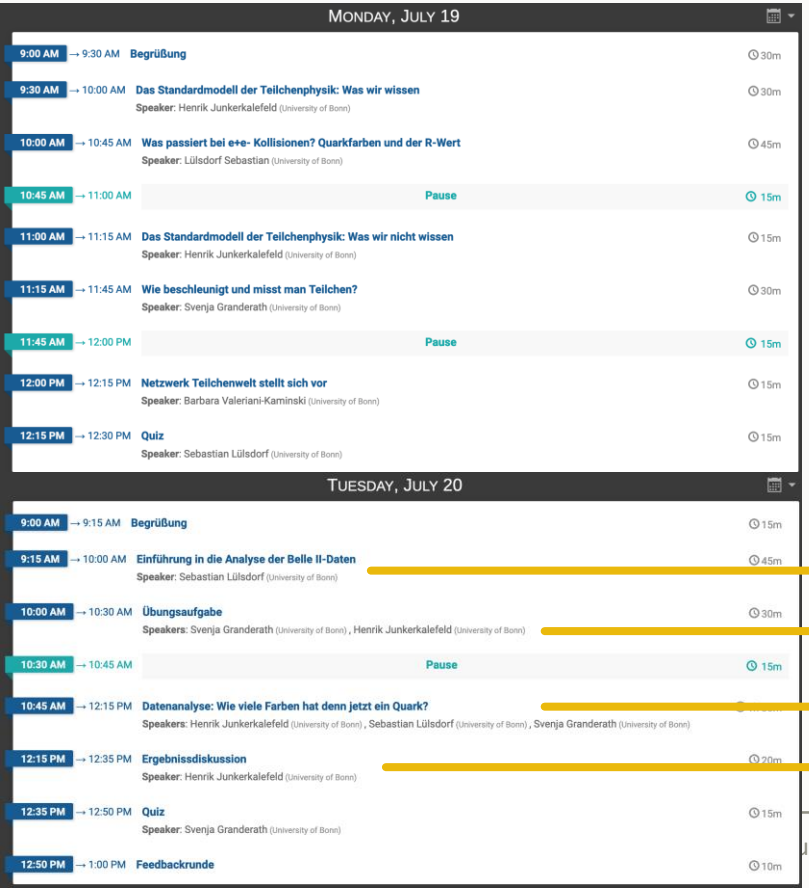


KAHOOT QUIZZES

Quizzes (day 1, day 2) that playfully probe the gained knowledge:

- of particle physics in general
- with respect to the R-value
- of the Belle II detector and its interaction with different particles

MATERIAL TO INTRODUCE DIFFERENT PROCESSES



Monday, July 19

9:00 AM → 9:30 AM	**Begrüßung**	30m
9:30 AM → 10:00 AM	**Das Standardmodell der Teilchenphysik: Was wir wissen** Speaker: Henrik Junkerkalefeld (University of Bonn)	30m
10:00 AM → 10:45 AM	**Was passiert bei e+e- Kollisionen? Quarkfarben und der R-Wert** Speaker: Lülsdorf Sebastian (University of Bonn)	45m
10:45 AM → 11:00 AM	**Pause**	15m
11:00 AM → 11:15 AM	**Das Standardmodell der Teilchenphysik: Was wir nicht wissen** Speaker: Henrik Junkerkalefeld (University of Bonn)	15m
11:15 AM → 11:45 AM	**Wie beschleunigt und misst man Teilchen?** Speaker: Svenja Granderath (University of Bonn)	30m
11:45 AM → 12:00 PM	**Pause**	15m
12:00 PM → 12:15 PM	**Netzwerk Teilchenwelt stellt sich vor** Speaker: Barbara Valeriani-Kaminski (University of Bonn)	15m
12:15 PM → 12:30 PM	**Quiz** Speaker: Sebastian Lülsdorf (University of Bonn)	15m

Tuesday, July 20

9:00 AM → 9:15 AM	**Begrüßung**	15m
9:15 AM → 10:00 AM	**Einführung in die Analyse der Belle II-Daten** Speaker: Sebastian Lülsdorf (University of Bonn)	45m
10:00 AM → 10:30 AM	**Übungsaufgabe** Speakers: Svenja Granderath (University of Bonn) , Henrik Junkerkalefeld (University of Bonn)	30m
10:30 AM → 10:45 AM	**Pause**	15m
10:45 AM → 12:15 PM	**Datenanalyse: Wie viele Farben hat denn jetzt ein Quark?** Speakers: Henrik Junkerkalefeld (University of Bonn) , Sebastian Lülsdorf (University of Bonn) , Svenja Granderath (University of Bonn)	
12:15 PM → 12:35 PM	**Ergebnissdiskussion** Speaker: Henrik Junkerkalefeld (University of Bonn)	20m
12:35 PM → 12:50 PM	**Quiz** Speaker: Svenja Granderath (University of Bonn)	15m
12:50 PM → 1:00 PM	**Feedbackrunde**	10m

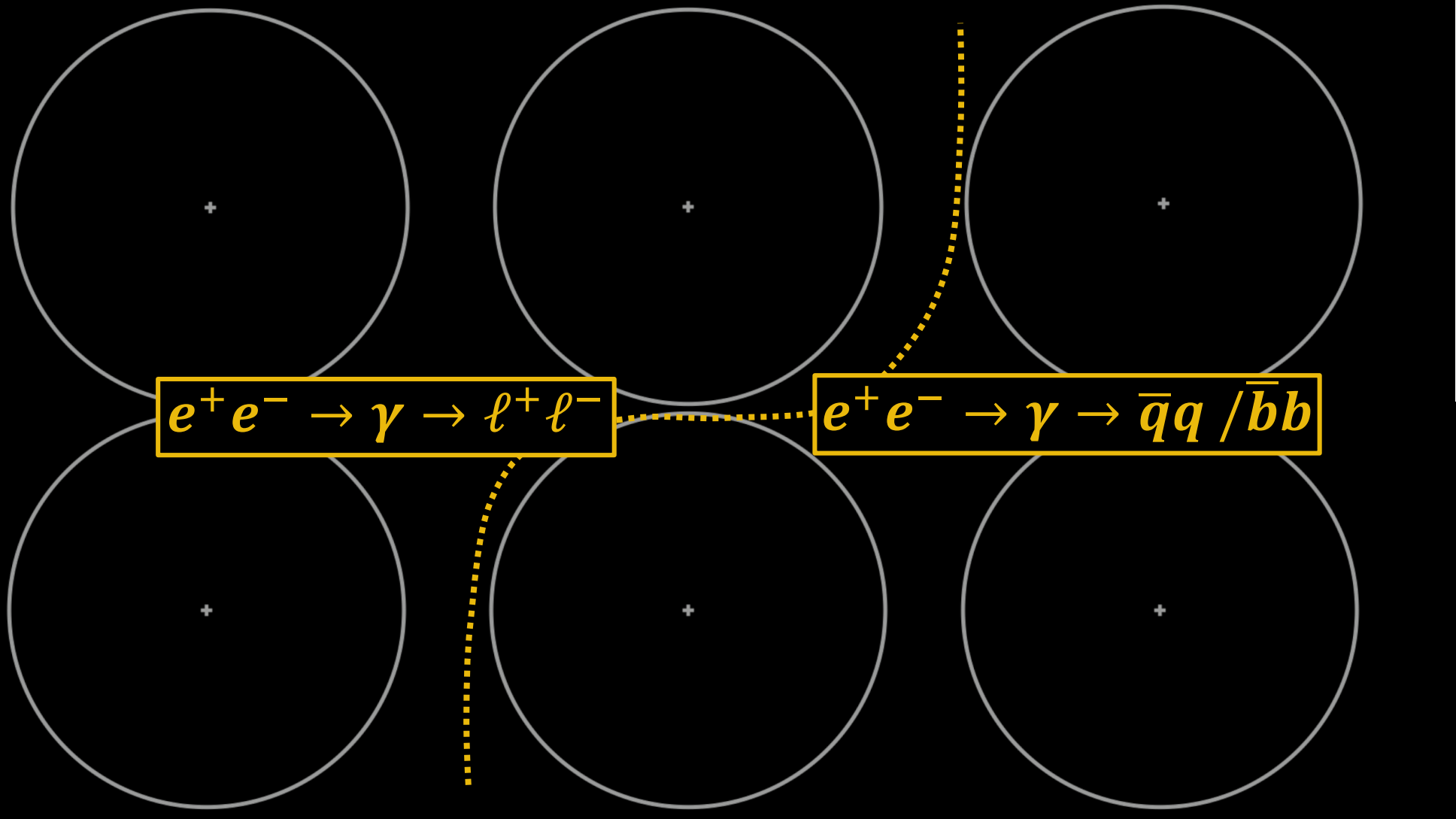
Introduction of event displays and pupil's exercise:

- How can we distinguish the different processes and why?
- Why can't we use e^+e^- and $\bar{b}b$ events to get the R-value?
- Concept of `foxWolframR2` aka "straightness"
- Concept of m^2_{miss} aka "missing energy"

SELF-EXPLANATORY WEBSITE

Pupils are guided through the exercise by a website that links the tasks

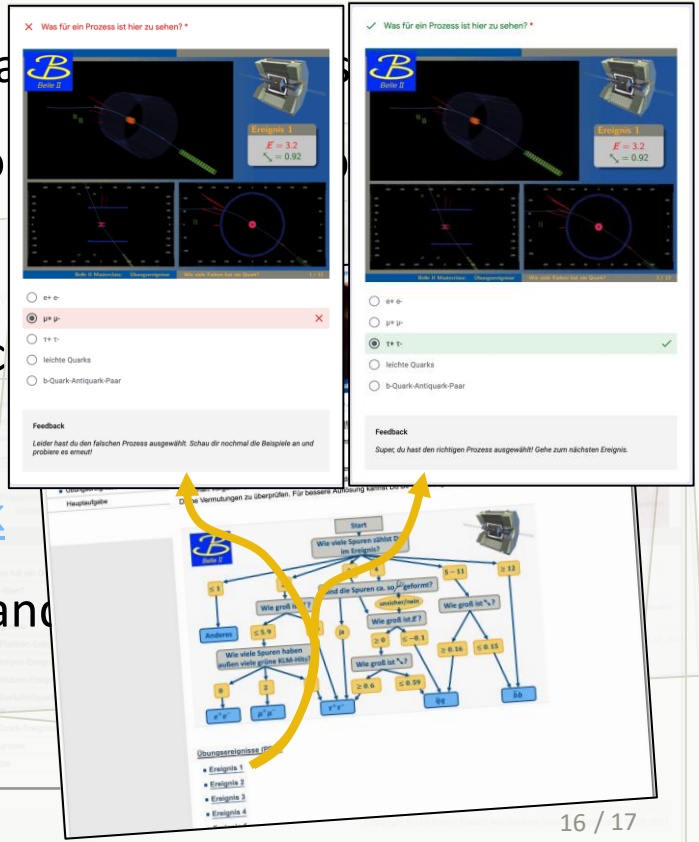
- The general task (measuring the number of quark col
- The R-value is introduced in a work sheet
- Example events are presented in which the differe
  outlined (event displays and **stopmotion videos**)


$e^+e^- \to \gamma \to \ell^+\ell^-$
$e^+e^- \to \gamma \to \bar{q}q\ /\bar{b}b$

WEBSITE CONTENT

Pupils are guided through the exercise by a website tha

- The general task (measuring the number of quark co
- The R-value is introduced in a work sheet
- Example events are presented in which the differenc outlined (event displays and **stopmotion videos**)
- 12 practice events are available with direct feedback
- Several datasets for the main exercise are available an



SUMMARY

- **Complete masterclass is developed and finished**. It ran like a clockwork.
- Several materials & **different tasks** are available to ensure **variety** for pupil
- Measurement is based on statistics, so the results actually improve the more events are evaluated ⇒ encourages joint work in **international masterclasses**