

Muon Finding in ZEUS

Achim Geiser ZEUS monday meeting 18.11.02

thanks to G. Abbiendi, L. Bellagamba, A. Bertolin, R. Brugnera,
A. Bruni, G. Bruni, M. Corradi, G. Grzelak, V. Kuzmin, A. Longhin,
B. Straub, F. Zarnecki, ...

- What is a muon?
- What is a muon in ZEUS?
- Example muon physics topics
- How to reconstruct muons?
- How to trigger on muons?
- How to analyze muons?

What is a muon ?

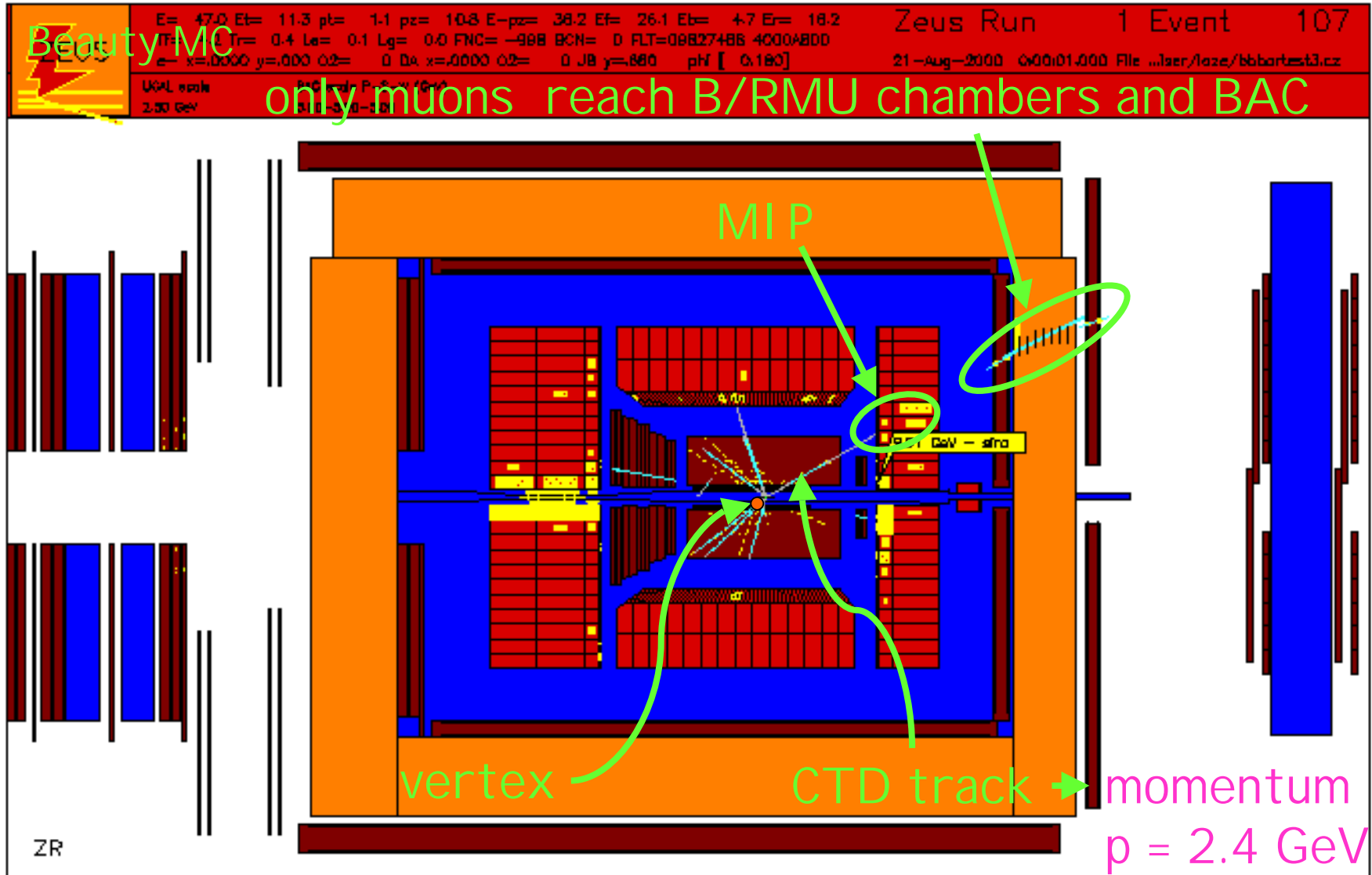
Minimum Ionizing Particle (MIP) with high penetration power

„rule of thumb“:

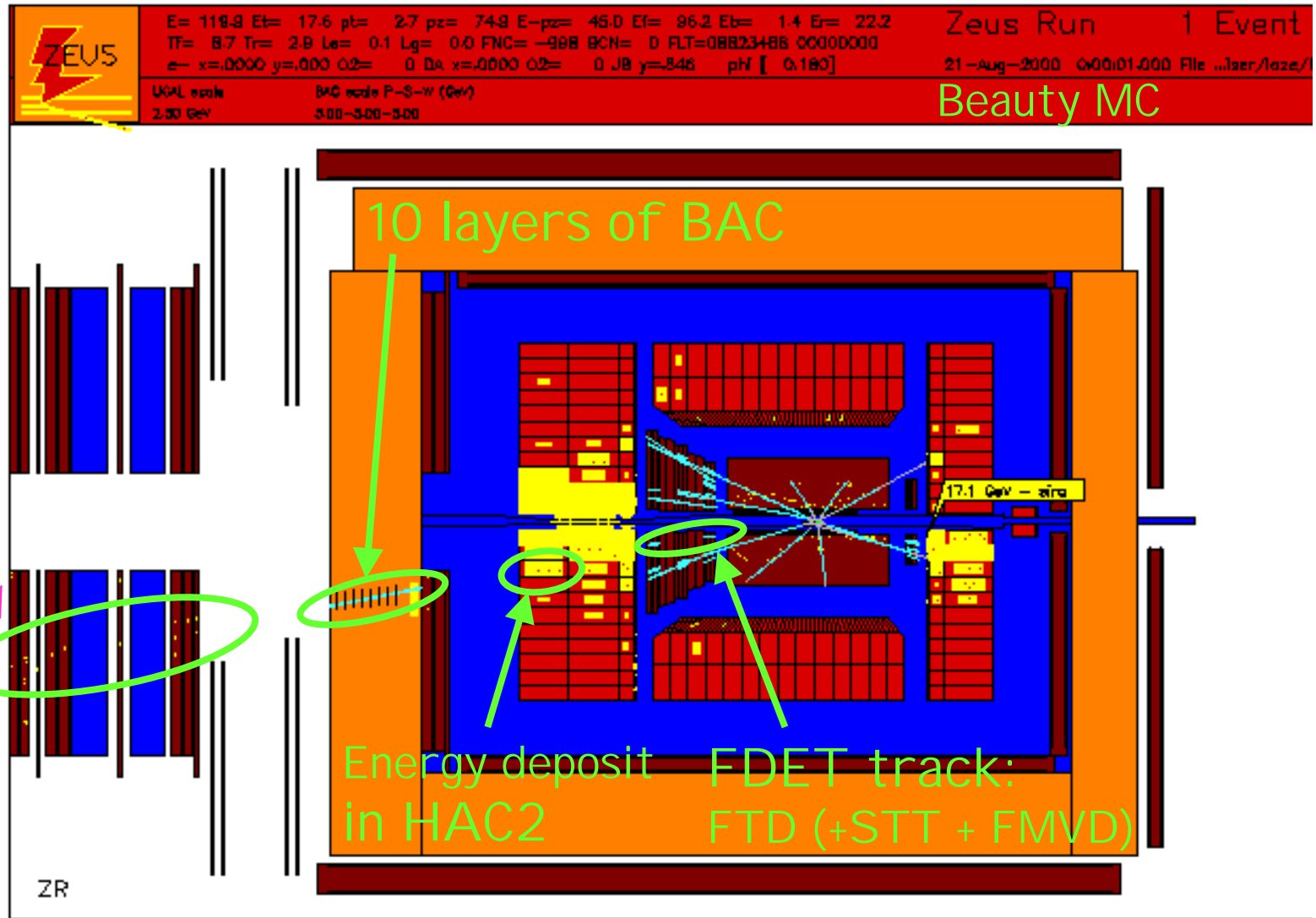
Range in iron: $\sim 1 \text{ m} / \text{GeV}$

to be compared to nuclear interaction length of $\sim 17 \text{ cm}$ (e.g. for pions)

What is a muon in ZEUS ?



What is a muon in ZEUS ?



Muon event display



Display of muon hits and tracks in ZEVI S being worked on, but not yet ready

-> use LAZE for the time being

Main detectors involved in muon I D

see detector lectures on ZEUS WWW page

■ Central Tracking Detector (CTD)

- | -> measures momentum, track isolation

■ Forward and Rear Tracking Detectors (FTD, RTD)

- | -> complement momentum measurement (regular tracking)

- since 2002: complemented further by MVD/STT

■ CALorimeter (CAL)

- | -> measures minimum ionization, isolation

■ Barrel and Rear MUon chambers (B/RMU)

Forward MUon chambers (FMU)

BACking Calorimeter (BAC)

- | -> measure penetration power, momentum consistency, minimum ionization

approximate detector thresholds

see detector lectures on ZEUS WWW page

all values are approximate, please check before using
analysis momentum thresholds are typically ~20-30% higher than detector thresholds

■	detector	threshold	pseudorapidity	■	detector	pseudorapidity
■	BMUON outer	$p_T > 2.5 \text{ GeV}$	-0.9 - 1.2	■	• CTD	-1.75-1.75
■	BMUON inner	$p_T > 1.2 \text{ GeV}$	-0.9 - 1.2	■	• FTD	
■	FMUON outer	$p > \sim 5 \text{ GeV}$	2.0 - 3.1	■	• STT	
■	FMUON wall	$p > \sim 4 \text{ GeV}$	1.3 - 2.0	■	• BMVD	-1.66-1.66
■	FMUON inner	$p > \sim 2.4 \text{ GeV}$	1.2 - 2.7	■	• FMVD	1.66-2.75
■	RMUON outer	$p > 2.2 \text{ GeV}$	-1.75 - -1.0			
■	RMUON inner	$p > 1.0 \text{ GeV}$	-1.75 - -1.0			
■	veto wall	$p > 2 \text{ GeV}$				
■	BAC central	$p_T > \sim 2.0 \text{ GeV}$)			
■	BAC forward	$p > \sim 2.8 \text{ GeV}$) continuous			
■	BAC rear	$p > 1.6 \text{ GeV}$)			
■	BCAL	$p_T > 1.1 \text{ GeV}$)			
■	FCAL	$p > 1.5 \text{ GeV}$) continuous			
■	RCAL	$p > 0.9 \text{ GeV}$)			

Example muon physics topics

- Charm and Beauty production from semileptonic decays (HFL)
- elastic and inelastic $J/\psi \rightarrow \mu\mu$ production (DIFF + HFL)
- High pt isolated muons (W, LQ, ...) (EXO)
- Bethe-Heitler muon pair production
- ...

Muon backgrounds

- muonic K and p decays
 - -> mainly low momentum non-isolated muons, sometimes detectable kink/not vertex associated
- hadronic shower leakage/punchthrough
 - -> mainly non-isolated muons, often momentum/range inconsistency
- matching ambiguities
 - -> only nonisolated muons
match wrong CTD track to real muon hits
- cosmic ray muons through nominal vertex
 - -> mainly isolated muons, sometimes mistaken for back-to-back muon pair

Muon reconstruction using CAL

MUONFIND: (+ many similar algorithms)

match **CAL MIP** island to **CTD track**

cut on Distance of Closest Approach and track momentum/pT

advantages:

simple algorithm, low p thr.,
large geometric coverage

disadvantages:

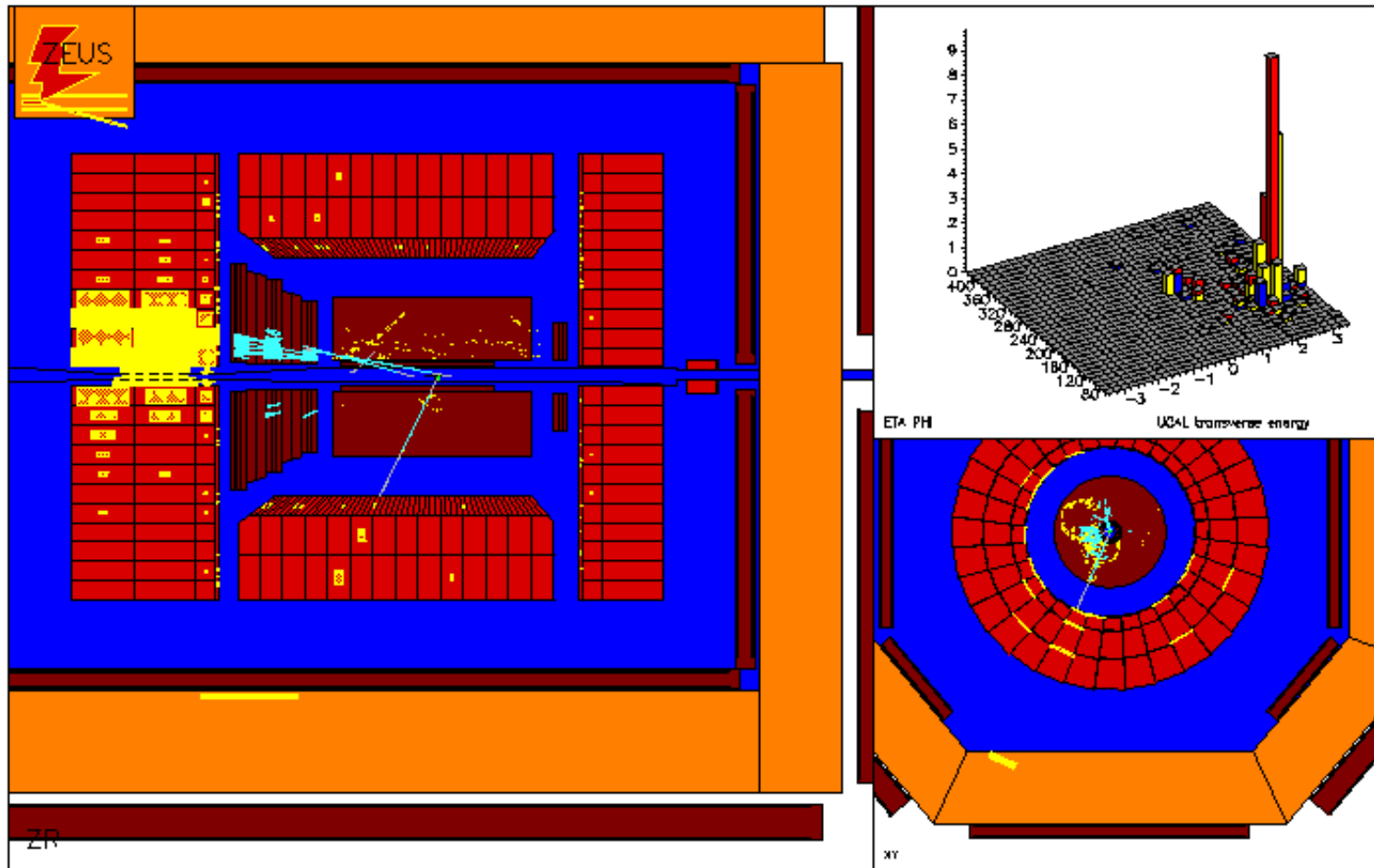
only for isolated muons
large background at low p

Suited for : - **high p isolated muons**
- **low p second muons (J/Y)**

High pt isolated muon candidate

http://www-zeus.desy.de/physics/exo/ZEUS_PUBLIC/plots/lathuile01/nicemuon-with-caption.eps.gz

$P_{T'}(\mu^+) = 38^{+20}_{-10}$ GeV, $P_{T'}^X = 36$ GeV, $A_{\text{coplanarity}} = 1.9$, $P_{T'} = 61^{+17}_{-8}$ GeV, $M_{T'} = 91^{+39}_{-19}$ GeV



Muon reconstruction using inner B/RMU

ZEUS note 93-120

GLOMU:

(GLOMU1, GLOEXO: without MIP match)

match **inner B/RMU segment** and **CAL MIP** to **CTD track**

cut on Distance of Closest Approach, angle match, and track momentum/pT

advantages:

fairly low p/pT threshold,
reasonably low background

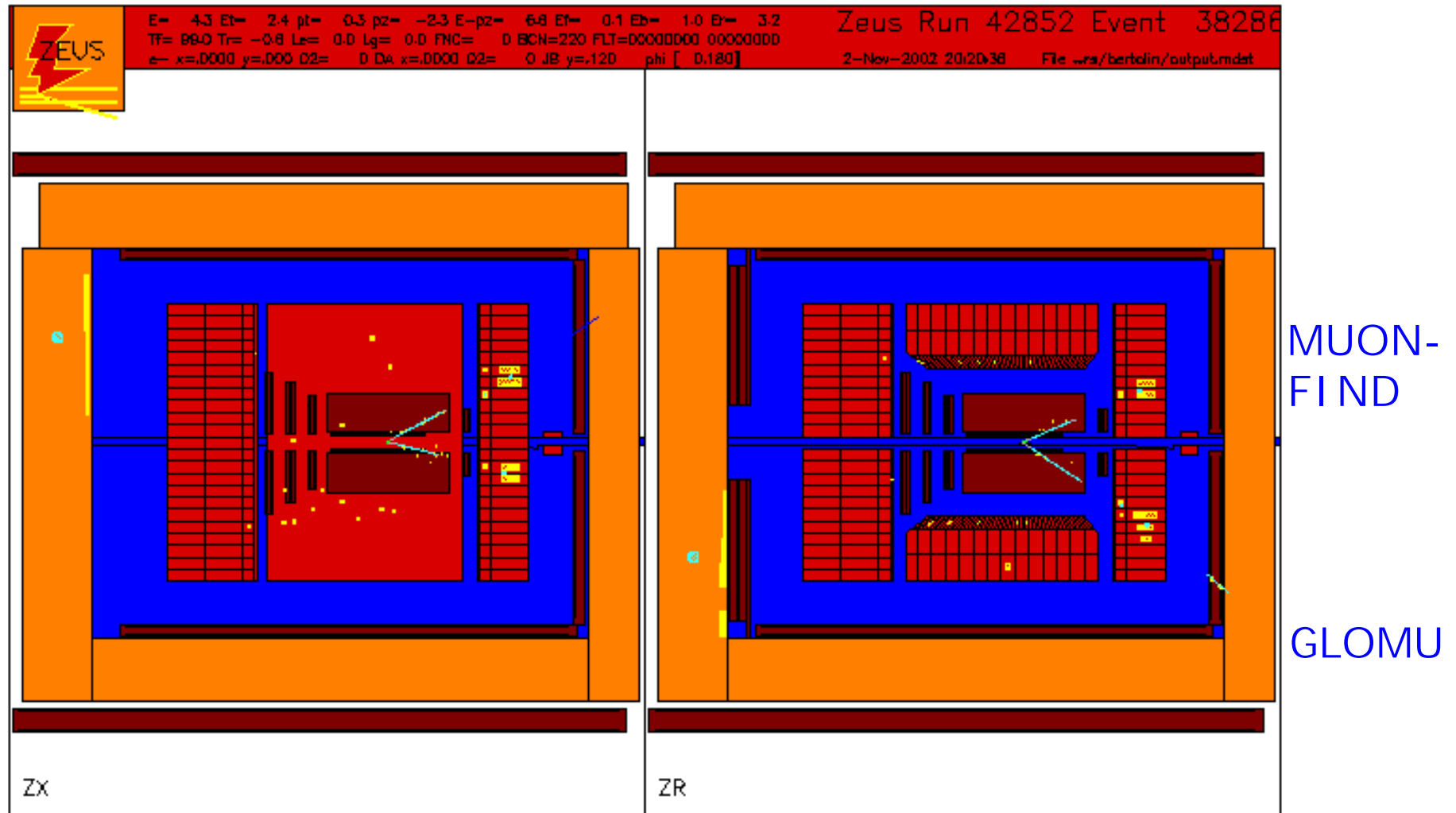
disadvantages:

only for semi-isolated muons,
reduced geometric coverage,
moderate efficiency

Suited for : - **medium p semi-isolated muons with moderate background** (+trigger)

2002 elastic J/Y candidate

courtesy A. Bertolin/A. Longhin



Muon reconstruction using BAC

http://www-zeus.desy.de/~robertc/ZEUS_ONLY/mubac.html

MUBAC:

reconstruct muon track segment in BAC

advantages:

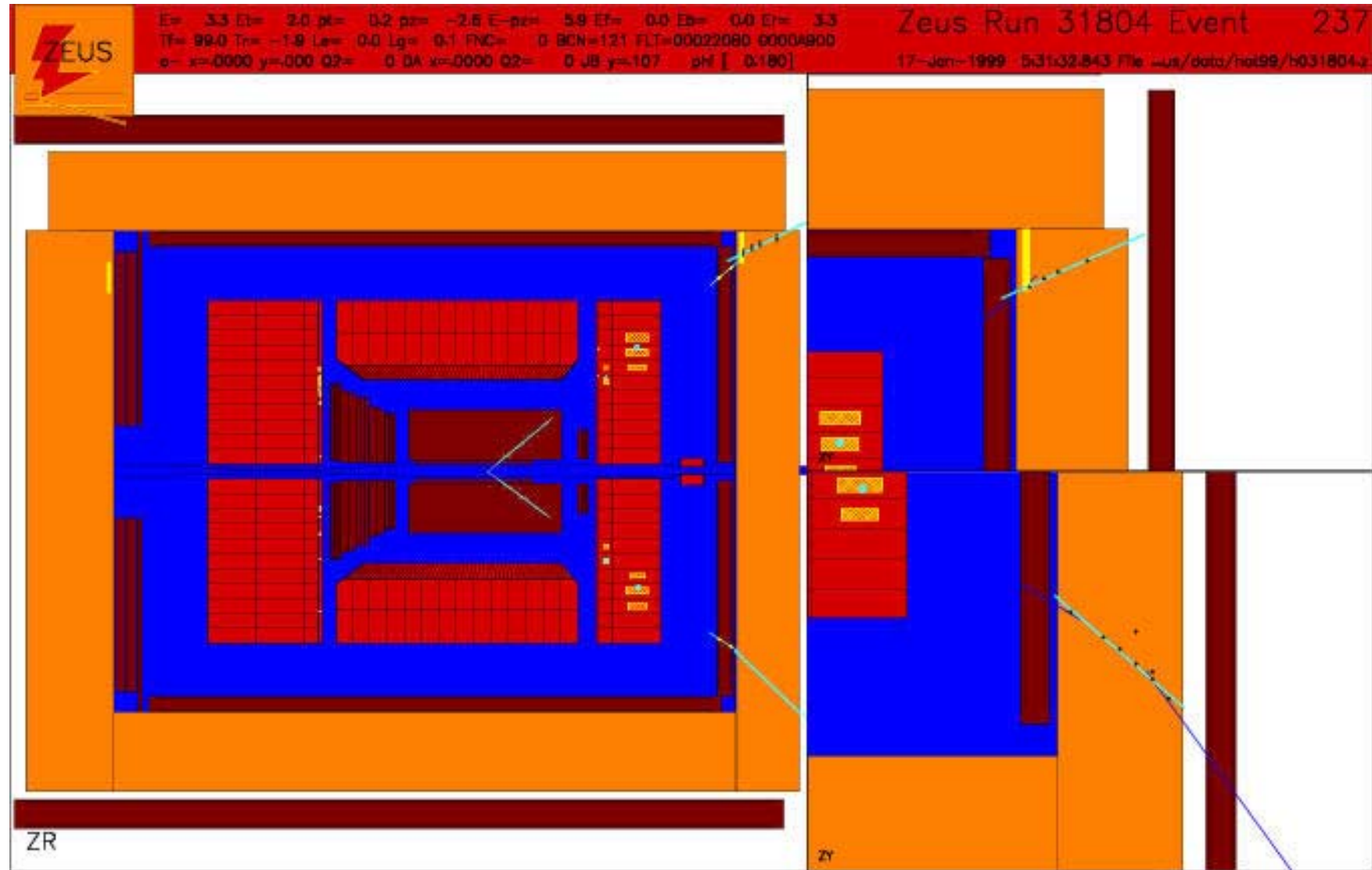
large geometric coverage,
clean signature (except
very forward)

disadvantages:

p threshold, match to CTD
or to other muon finder
needs to be done by user

Suited for : - use with other algorithms

J/ Υ candidate identified with MUBAC



Isolated muon reconstruction using FMU

G. Bruni

MAMMA: (used by MFFASE, ...)

match **FMU track/hits** to **CAL MIP** and **CTD/FTD track**, many different modes

advantages:

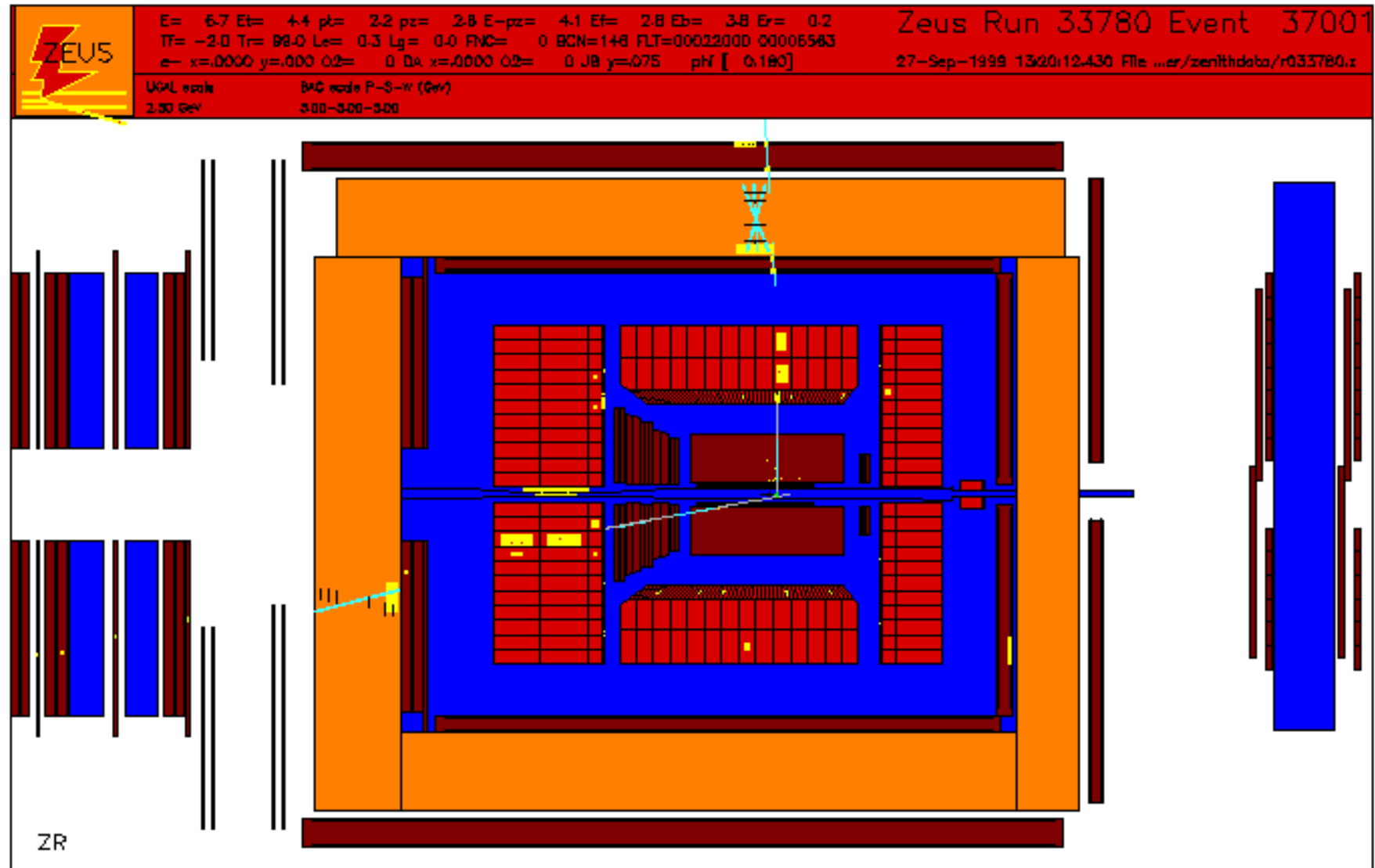
more reliable muon ID
than CTD/CAL match only

disadvantages:

forward isolated muons only,
FMU efficiency,
higher momentum threshold

Suited for : -**forward isolated muons** (+trigger)

High mass dimuon candidate (57 GeV?)



Muon reconstruction using inner + outer B/RMU

G. Abbiendi, ZEUS note 99-063

BREMAT: use GEANE extrapolation + Kalman filter
match **inner + outer BRMU segments** to **CTD track**
cut on matching probability (position, angle, momentum consistency)
two modes: inner BRMU only (4 d.o.f.), inner+outer BRMU (5 d.o.f.)

advantages:

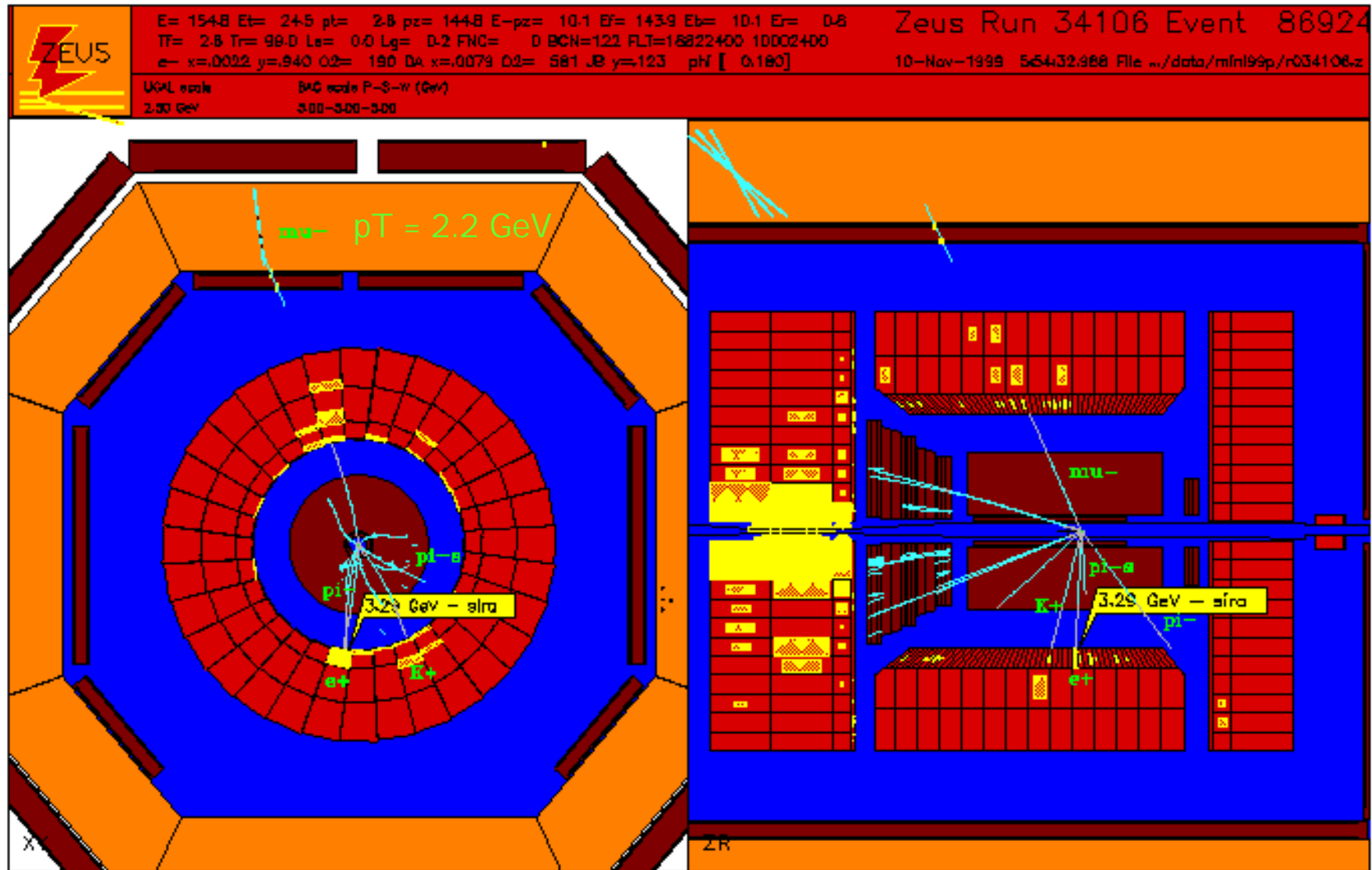
sophisticated algorithm,
low background,
no isolation requirement

disadvantages:

reduced geometric coverage,
BRMU efficiency ~60-70%,
momentum threshold

Suited for : - **medium to high p muons,**
including semileptonic decays

$b\bar{b} \rightarrow D^* e^+ X, m^- X$ candidate



Nonisolated muon with 4 jets

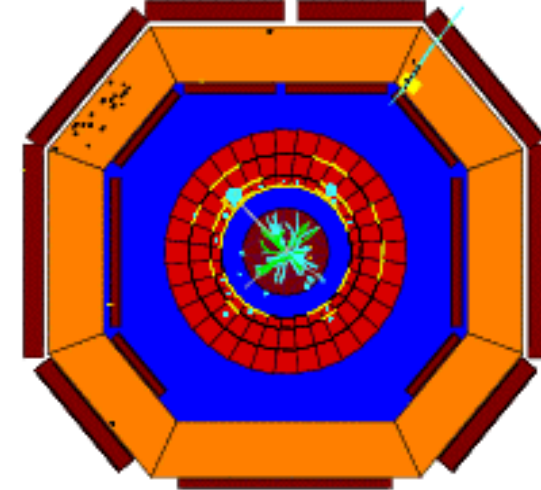
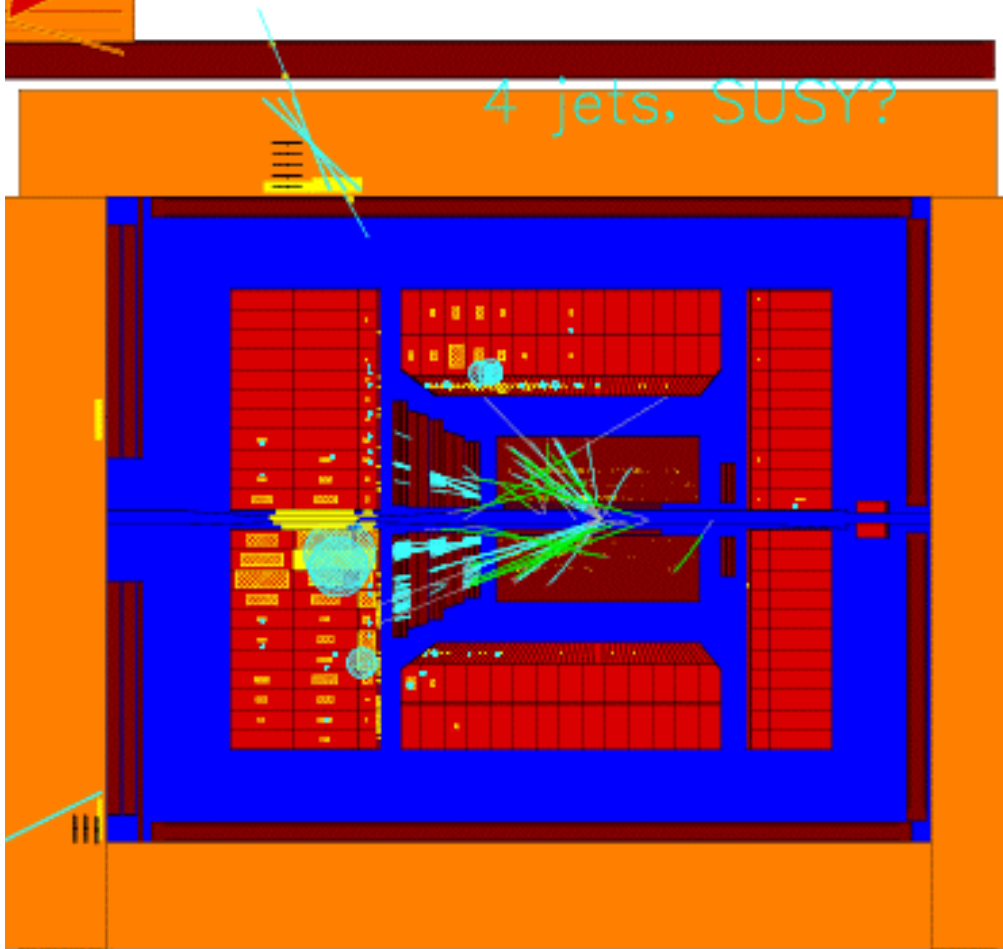
ZEUS

E= 381.3 Et= 121.2 pt= 6.8 pz= 342.8 E-pz= 38.5 Ef= 317.7 Eb= 82.9 Er= 0.7
Tf= 1.2 Tr= 99.0 Le= 0.0 Lg= 0.1 FNC= 0 BCN=166 FLT=18A23F00 10006000
e- x=-.0000 y=-.000 Q2= 0 DA x=-.0000 Q2= 0 JB y=-.699 phi [0.180]

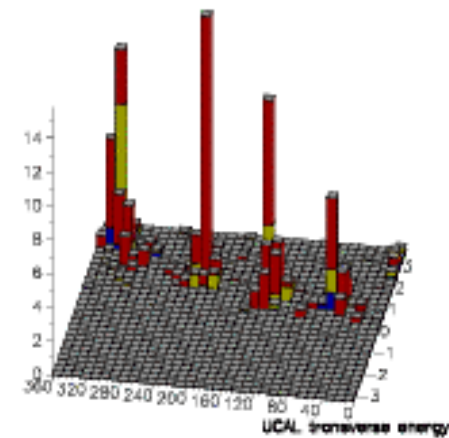
Zeus Run 35893 Event 42

12-Apr-2000 21:02:05.797 File --s/data/hot00p/h0

4 jets, SUSY?



XY



ETA PHI

UCL transverse energy

R

Isolated muon reconstruction using CAL (+ B/RMU)

V. Kuzmin, /zow/user/kuzmin/mv/src/mv/mv.fpp

MV: see also V. Kuzmin, Nucl. Instr. Meth. A 453 (2000) 336

match **CAL cell pattern** to **CTD track**

also use **HES MIP** and **B/RMU** if available (uses BREMAT)

sophisticated probability evaluation of MIP compatibility

advantages:

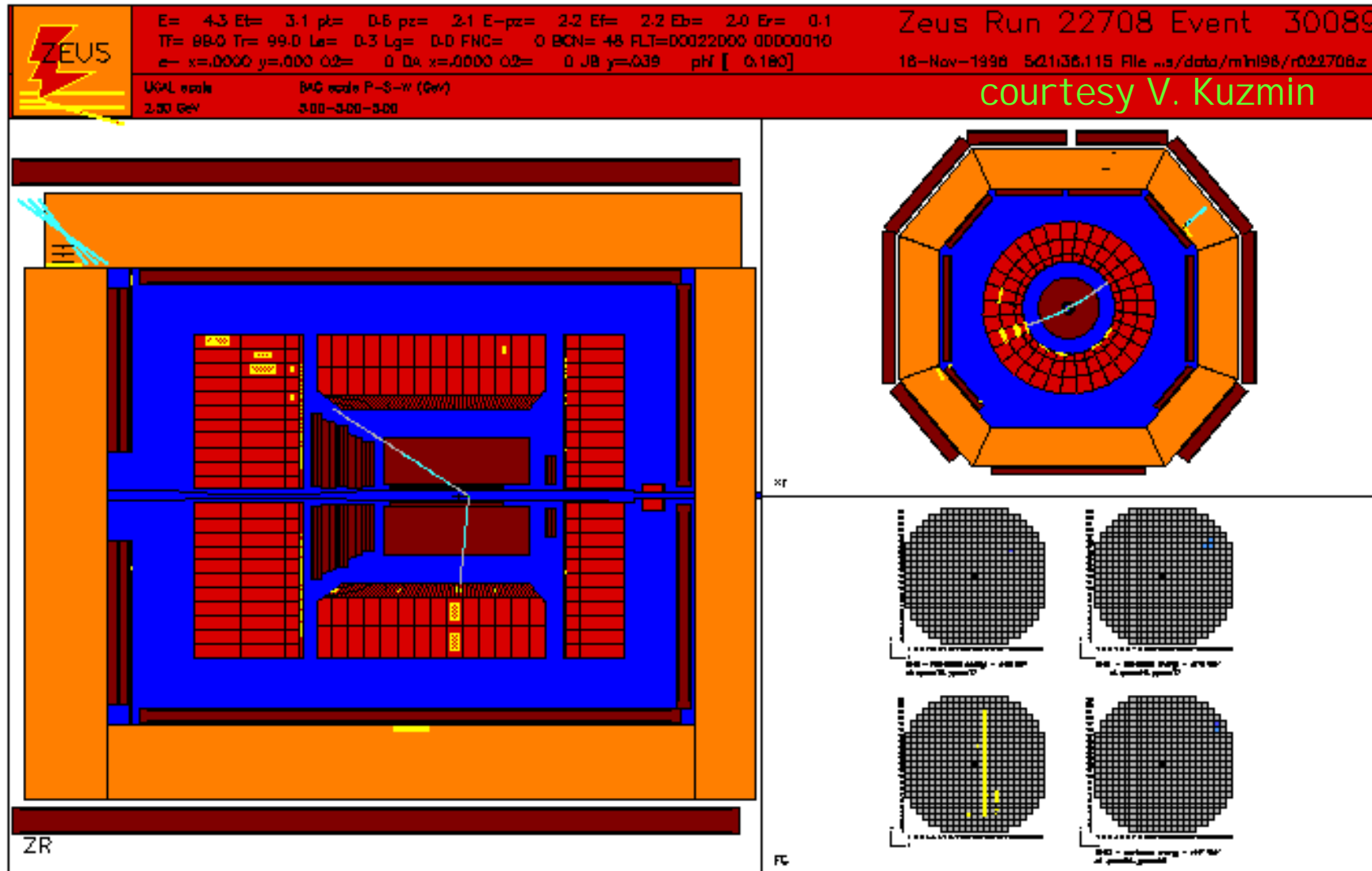
sophisticated CAL MIP
algorithm (+BREMAT)
low momentum threshold,
good geometrical coverage

disadvantages:

isolated muons only,
large hadronic background
at low p for CAL-only mode

Suited for : - **(low p) isolated muons, dimuons**

Dimuon candidate from MV finder ($m \sim 5$ GeV)



Nonisolated muon reconstruction using FMU

M. Corradi, http://www-zeus.desy.de/~corradi/ZEUS_ONLY/mpmatch/mpmatch2.html

MPMATCH: (based on MVMATCH, L. Bellagamba, ZEUS note 56/051)

match **FMU track** to **CTD track**

same basic method as BREMAT (GEANE/Kalman filter) for FMU

advantages:

sophisticated algorithm,
momentum fit incl. FMU,
no isolation requirement

disadvantages:

limited to FMU-CTD overlap
region, FMU efficiency,
high momentum threshold

Suited for : - **high p nonisolated forward muons,
including semileptonic decays**

Muon reconstruction using FMU + BAC

G. Bruni, http://www-zeus.desy.de/~bruni/ZEUS_ONLY/muons.html

MUFO:

match **FMU track** to **CTD track** and **BAC**

similar to MPMATCH/MVMATCH, uses MUBAC,
momentum fit from FMU+CTD,
BAC for additional background rejection

advantages:

disadvantages:

same as for MPMATCH

Suited for : - **alternative to MPMATCH**

Triggering on muons

see general + physics groups trigger pages

- **FLT**: trigger on segments in B/RMU,
hit patterns in FMU,
complement by CAL MIP or minimum energy,
new BAC FLT in preparation
- **SLT**: add timing cut (against cosmics) for B/RMU,
perform simple track fit for FMU,
or trigger on high pt isolated track,
complement by CAL mip or minimum energy
- **TLT** : Run simple muon reconstruction algorithms:
 - GLOMU (with) or GLOEXO/GLOMU1 (without CAL MIP requirement) for B/RMU
 - MAMMA (isolated muons) + related algorithms (nonisolated muons) for FMU, major update in pipeline
 - new online versions of MV and MUBAC in pipelinepartially complement by requirement of jets, 2nd leptons, etc.

How to analyze muons ?

- Muon algorithms currently implemented in ORANGE:

(see ORANGE documentation)

- GLOMU (finder 1) for B/RMU

- MAMMA/MFFASE (finder 2) for FMU

- MUONFIND (finder 3) for CAL MIP

reasonably suited (and used) for isolated muon (EXO) and dimuon / J/Y (DIFF, HFL) analyses

- MUBAC for BAC used for Bethe-Heitler dimuon analysis

- Will soon be upgraded by addition of more sophisticated, so far „private“ algorithms: (also see ORANGE lecture B. Straub)

- BREMAT for B/RMU

- MPMATCH for FMU

- MV for CAL MIP

-> also suited for semileptonic (nonisolated) muons (HFL, DIFF), improved background rejection for all analyses (EXO, DIFF, HFL)

How to analyze muons ?

- **Other plans for near future:** (currently under discussion with muon experts and B. Straub)
 - Allow user to choose which of these finders should be active in ORANGE.
 - Design general muon block with most important muon information, with format INDEPENDENT of the chosen finder. Optionally, this will be in addition to the existing muon blocks (with cross reference) for backwards compatibility.
 - Try to combine information from different finders into single entry as much as possible (e.g. BREMAT/MV/MUBAC)
 - Provide flags to store minimal information (general muon block) only for „standard“ user, or full information from each finder for experts
- **Your input/opinion/comments to these plans are welcome!**

Conclusions

- The ZEUS detector is **very well suited for muon detection** (a lot of redundancy)
- So far, most analyses do **not yet use the full detector potential** (e.g. sophisticated matching algorithms, BAC)
- A planned upgrade of ORANGE should make it possible to **use this full potential without having to be an expert**
- Trigger and algorithm upgrades, higher luminosity, and new detectors (MVD, STT) will allow **significant improvements of muon based physics results** from upgrade running
-> **Please take muon detectors serious when on shift!**