

# TOP reconstruction and simulation studies IV

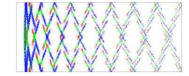
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**8-July-2009**

3rd Open meeting of the Belle II

- ❖ Reconstruction software (TOPsimrec)
- ❖ Comparison: focusing i-TOP vs. f-TOP

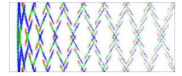


## Status of reconstruction code

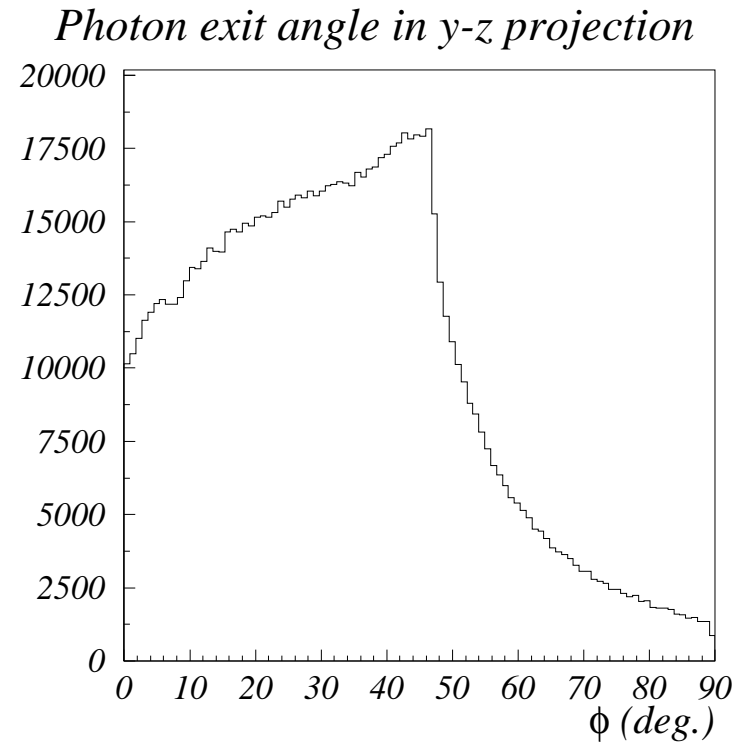
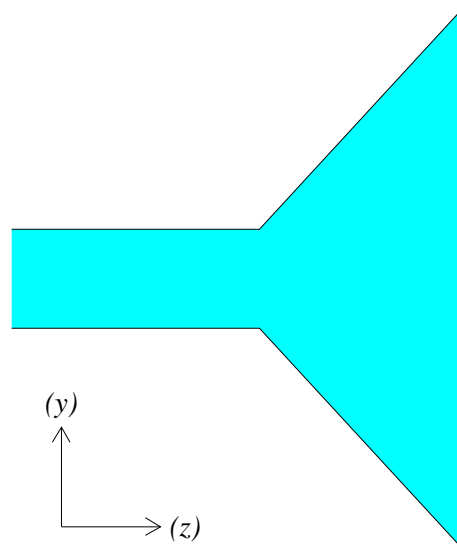
- ❖ First version of TOPsimrec become available from beginning of June
  - ▷ based on F77 code
  - ▷ C++ user interface provided
  - ▷ short write-up on how to use included
- ❖ Can be downloaded from <http://www-f9.ijs.si/staric/TOP/>
- ❖ New version almost ready
  - ▷ includes **i-TOP simulation/reconstruction**
  - ▷ will make it available in the next days (same location)



## Remark on expansion volume design



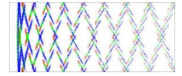
From the reconstruction point of view ...



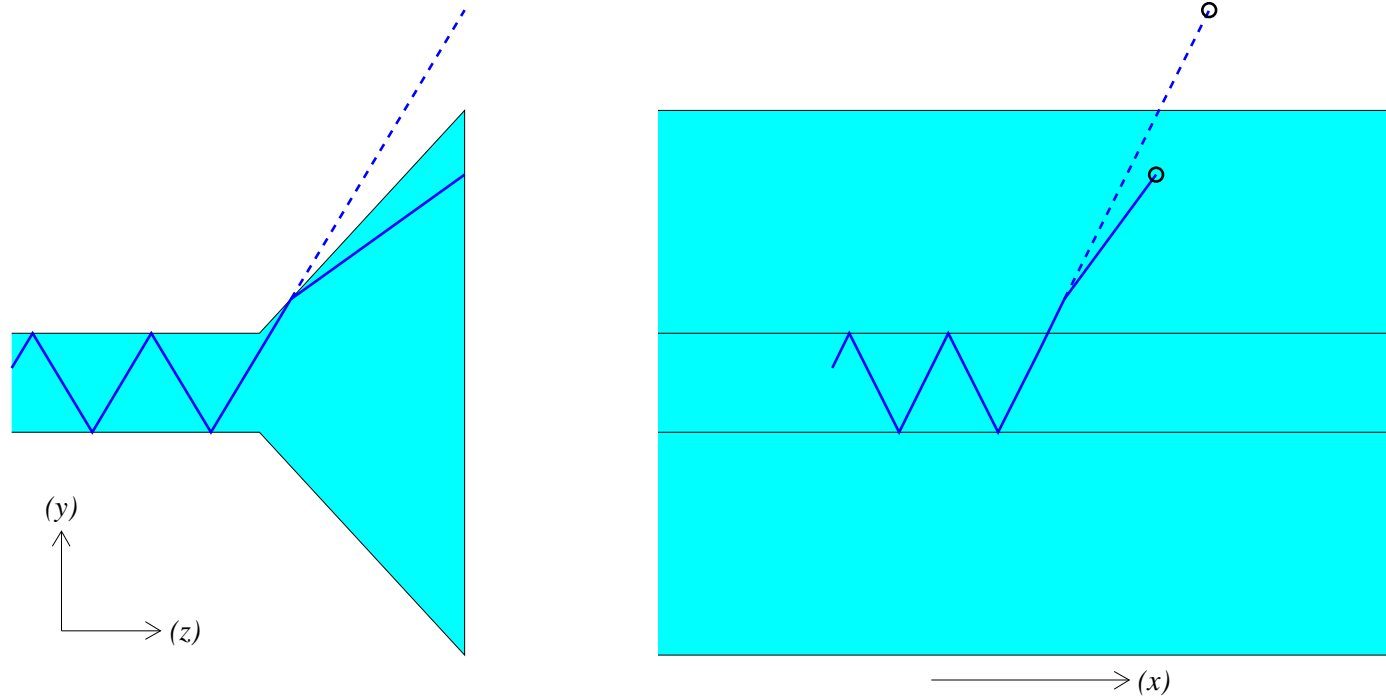
- ▷ a fraction of photons hit the upper/lower sides of expansion volume
- ▷ most of them (all?) are totally reflected into the exit window (e.g. not lost)



## Remark on expansion volume design



From the reconstruction point of view ...

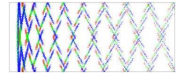


- ▷ at exit window: true hit  $x$  position and the extrapolated one are **different**
- ▷ makes complications for the PDF construction

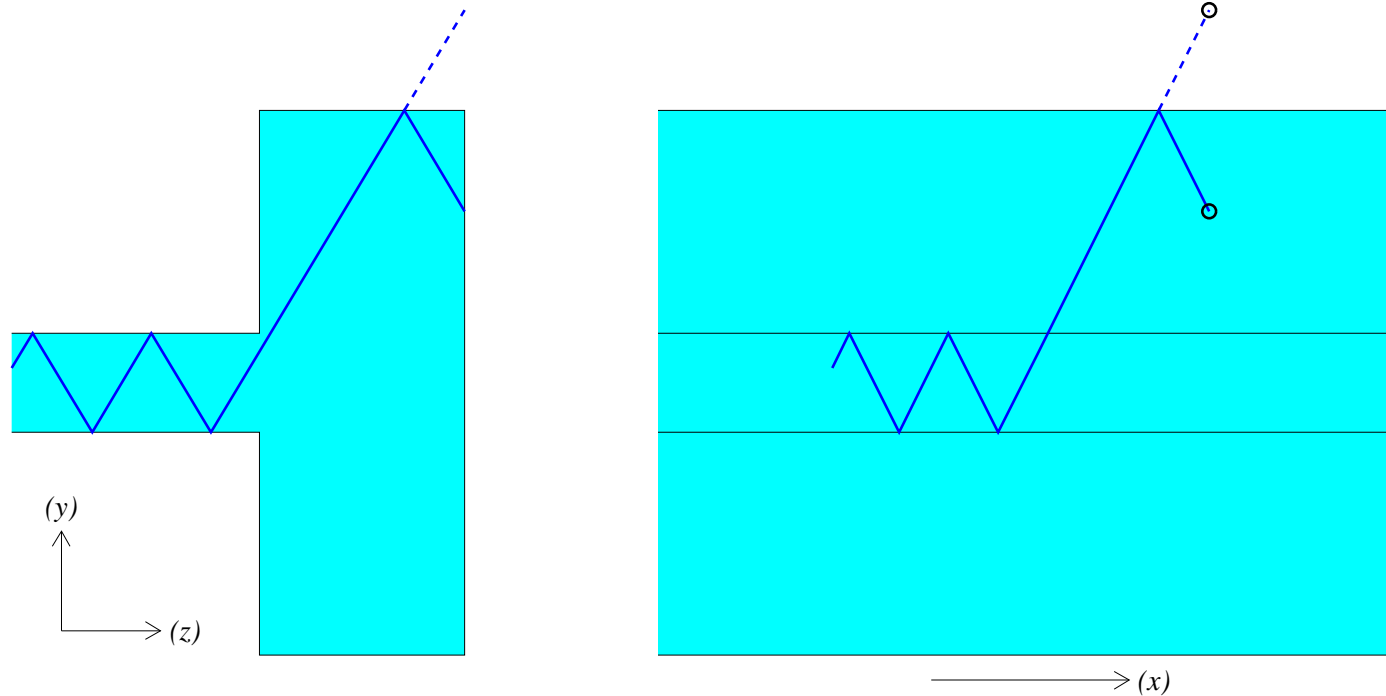
Reconstruction: **not fully implemented (yet)**



## Remark on expansion volume design

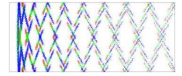


From the reconstruction point of view ...



- ▷ at exit window: true hit  $x$  position and the extrapolated one are **the same**
- ▷ much easier to implement

Reconstruction: **ready**



## *TOPsimrec: a short tutorial*

### Directory structure:

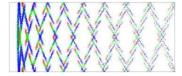
docu	documentation
<b>examples</b>	<b>examples and makefile</b>
hbo	place for the output hbook file(s) from top_simu.cc
<b>include</b>	<b>C++ include files (user interface)</b>
obj	place for compiled (object) files
paw	paw macros to analyze output from top_simu.cc
<b>src</b>	<b>C++ source code</b>
srcF77	F77 source code

### Include:

RandomParticle.h	
<b>TOPconfig.h</b>	TOP counter configuration functions
TOPf77fun.h	
TOPhbook.h	
<b>TOPreco.h</b>	interface class to reconstruction
<b>TOPsimu.h</b>	interface class to simulation
<b>TOPutil.h</b>	data conversion utilities (for debugging etc.)



## Example 1: 2-readout f-TOP



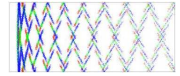
```
#include "TOPconfig.h"

void TOPconfigure () {
    TOPvolume(115, 125, -80, 190);
    setBfield(1.5);
    setPMT(2.75, 2.75, 2.2, 2.2, 1, 4);
    double frac[3]={0.5815, 0.2870, 0.1315};
    double mean[3]={-13.59e-3, 29.03e-3, 273.0e-3};
    double sigma[3]={31.97e-3, 53.39e-3, 340.2e-3};
    setTTS(3, frac, mean, sigma);
    setQE("qe_GaAsP400nm.dat", 0.35);
    setTDC(10, 50.E-3);

    int n=18;
    double Dphi=2*Pi/n; double Phi=0; int id;
    for(int i=0; i<n; i++){
        id=setQbar(40, 2, -78, 107, 118, 0, Phi, PMT, SphericM);
        setMirrorRadius(id, 500);
        id=setQbar(40, 2, 108, 183, 118, 0, Phi, None, PMT);
        Phi+=Dphi;}
    TOPfinalize ();
}
```



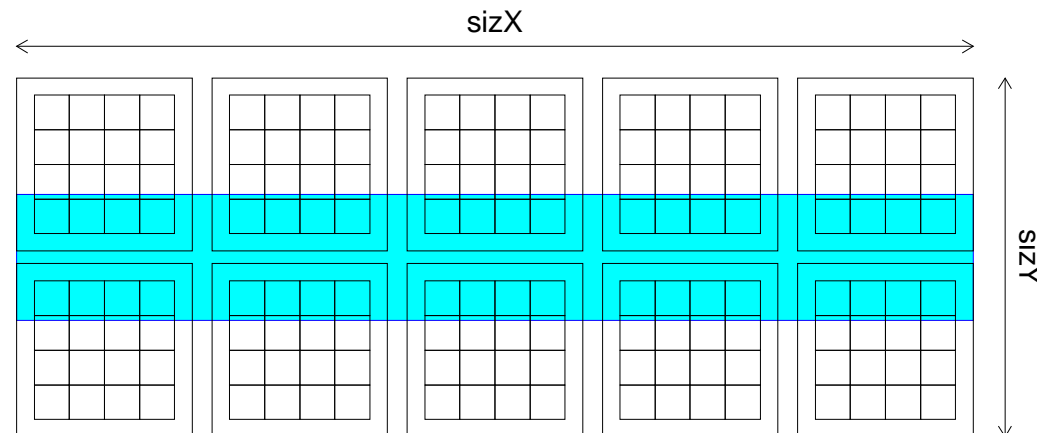
## Example II: focusing *i*-TOP



```
int n=16;  
double Dphi=2*Pi/n; double Phi=0; int id;  
for(int i=0; i<n; i++){  
    id=setQbar(44, 2, -80, 190, 115.8, 0, Phi, PMT, SphericM);  
    setMirrorRadius(id, 720);  
    addExpansionVolume(id, Left, Box, 4.14, 11.0);  
    Phi+=Dphi;}
```

- ❖ PMT's are arranged automatically on the exit window
- ❖ can be re-arranged with:

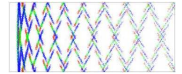
```
arrangePMT(int QbarID, double sizX, double sizY)
```







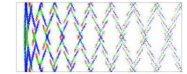
## Example III: reconstruction



```
#include "TOPreco.h"

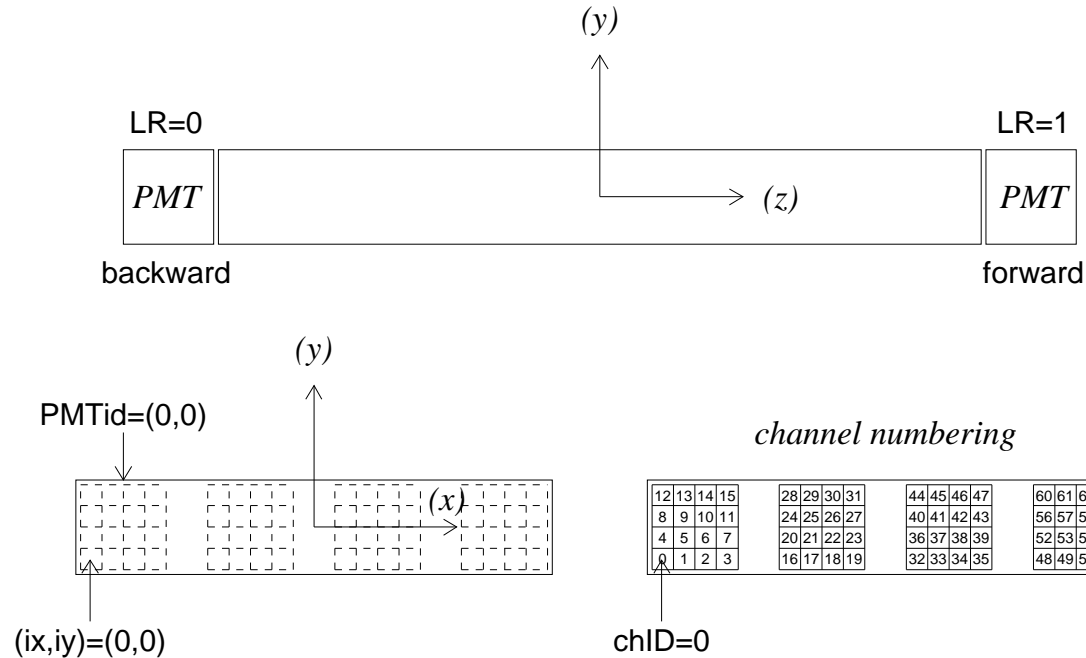
double Masses[3]={.13957, .49368, .93827}; int Nhyp=3;
double Bkg=1.5; // expect this number of background hits for ex.

void RecEvent(){
  TOPreco reco(Nhyp, Masses, Bkg);
  reco.Clear();
  for (...){ //loop over your digitized data (all bars)
    ...
    reco.AddData(QbarID, chID, TDC);
  }
  for (...){ //loop over tracks
    ...
    reco.Reconstruct(x,y,z,t,px,py,pz,q);
    if (reco.Flag() == 1) {
      double LogL[Nhyp], ExpPhot[Nhyp]; int Nphot;
      reco.GetLogL(Nhyp, LogL, ExpPhot, Nphot);
      ...
    }
  }
}
```



# Channel numbering

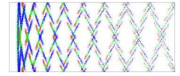
```
reco.AddData(QbarID, chID, TDC)
```



- ❖ If backward equipped (LR=0)  
 $chID = ix + Nx * (iy + Ny * (PMTidX + NumPMTx(LR, QbarID) * PMTidY))$
- ❖ If forward equipped (LR=1)  
 $chID = NumCh(LR=0) + ix + Nx * (iy + Ny * (PMTidX + NumPMTx(LR, QbarID) * PMTidY))$
- ❖ To x-check use functions defined in include/TOPutil.h



## CPU and memory consumption



Jobs run on B computers:

- ❖ Simulation and reconstruction of 500 000 single-track events per job
- ❖ Tracks (half pions half kaons) uniformly over  $4\pi$ , uniformly in  $0 < p < 5$  GeV/c
- ❖ 65% tracks in the acceptance,  $\pi$  and  $K$  mass hypotheses used

### SL-10, 1×4

configuration	CPU (rec/tot)	Max memory
2-readout f-TOP	22 min. (38%)	11 MB
focusing i-TOP	50 min. (73%)	14 MB

### SL-10, 4×4

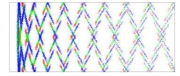
configuration	CPU (rec/tot)	Max memory
2-readout f-TOP	45 min. (67%)	14 MB
focusing i-TOP	150 min. (91%)	27 MB

- ❖ CPU time for recon. per track (in acceptance) per mass hypothesis:

configuration	SL-10, 1×4	SL-10, 4×4
2-readout f-TOP	0.8 ms	2.8 ms
focusing i-TOP	3.4 ms	12.6 ms



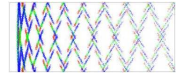
## Study of focusing *i*-TOP and *f*-TOP



### Detector configurations

- ❖ PMT: Hamamatsu SL-10 with  $1 \times 4$  or  $4 \times 4$  channels
- ❖ TTS: 3-gaussian (fitted Inami-san's distribution)
- ❖ QE: GaAsP with 400nm filter (sharp cutof), 35% CE
- ❖ CFD: 500ps delay, 5ns pileup time
- ❖ TDC: 10 bit, 50ps/ch, multihit ( $>5$ ns)
- ❖ 16 detector segments in  $\phi$  at  $R = 115.8$  cm
- ❖ Q-bars:  $44 \times 2$  cm<sup>2</sup>
- ❖ Focusing with spherical mirror
- ❖ *i*-TOP expansion volume:  $\Delta z = 4.14(8.28)$  cm, 11 cm high, box-shaped

configuration	$z_1$	$z_2$	$R_{\text{mirror}}$	num.PMT	$\Delta z$
2-readout <i>f</i> -TOP	-80 cm	107 cm	500 cm	16	
	108 cm	190 cm		16	
1-readout <i>f</i> -TOP	-80 cm	190 cm	720 cm	16	
focusing <i>i</i> -TOP (1)	-80 cm	190 cm	720 cm	$4 \times 16$	4.14 cm
focusing <i>i</i> -TOP (2)	-80 cm	190 cm	720 cm	$4 \times 16$	8.28 cm

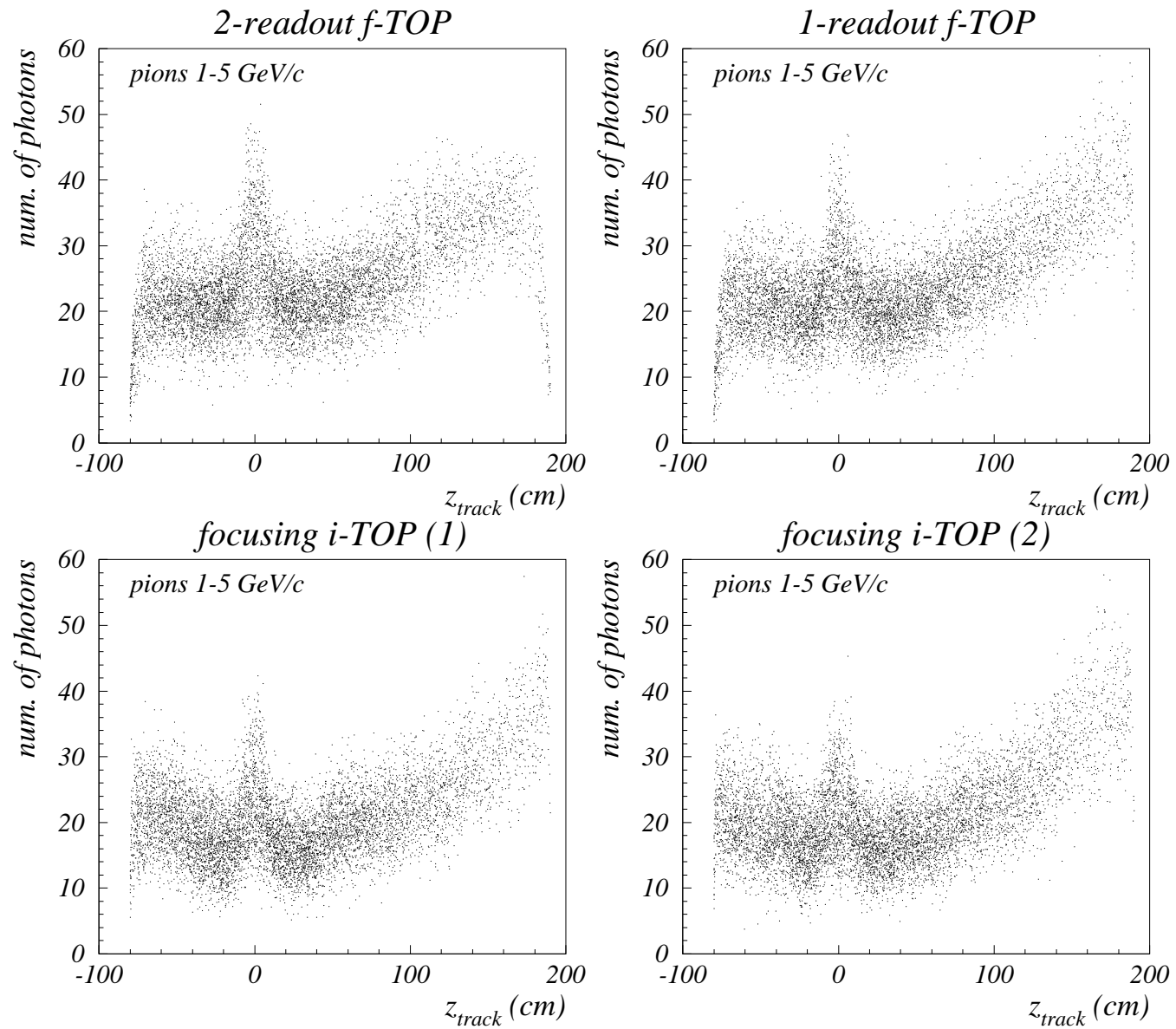
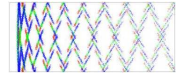


## Simulation

- ❖ Pions and kaons (half-half) of both charges distributed uniformly over  $4\pi$  with momenta distributed uniformly between 0 and 5 GeV/c
- ❖ 500 000 tracks/job
- ❖ Magnetic field  $B=1.5$  T
- ❖ Background/bar/50ns: 20 hits uniformly distributed
- ❖  $T_0$  jitter: 10 ps (rms) or 25 ps (rms)

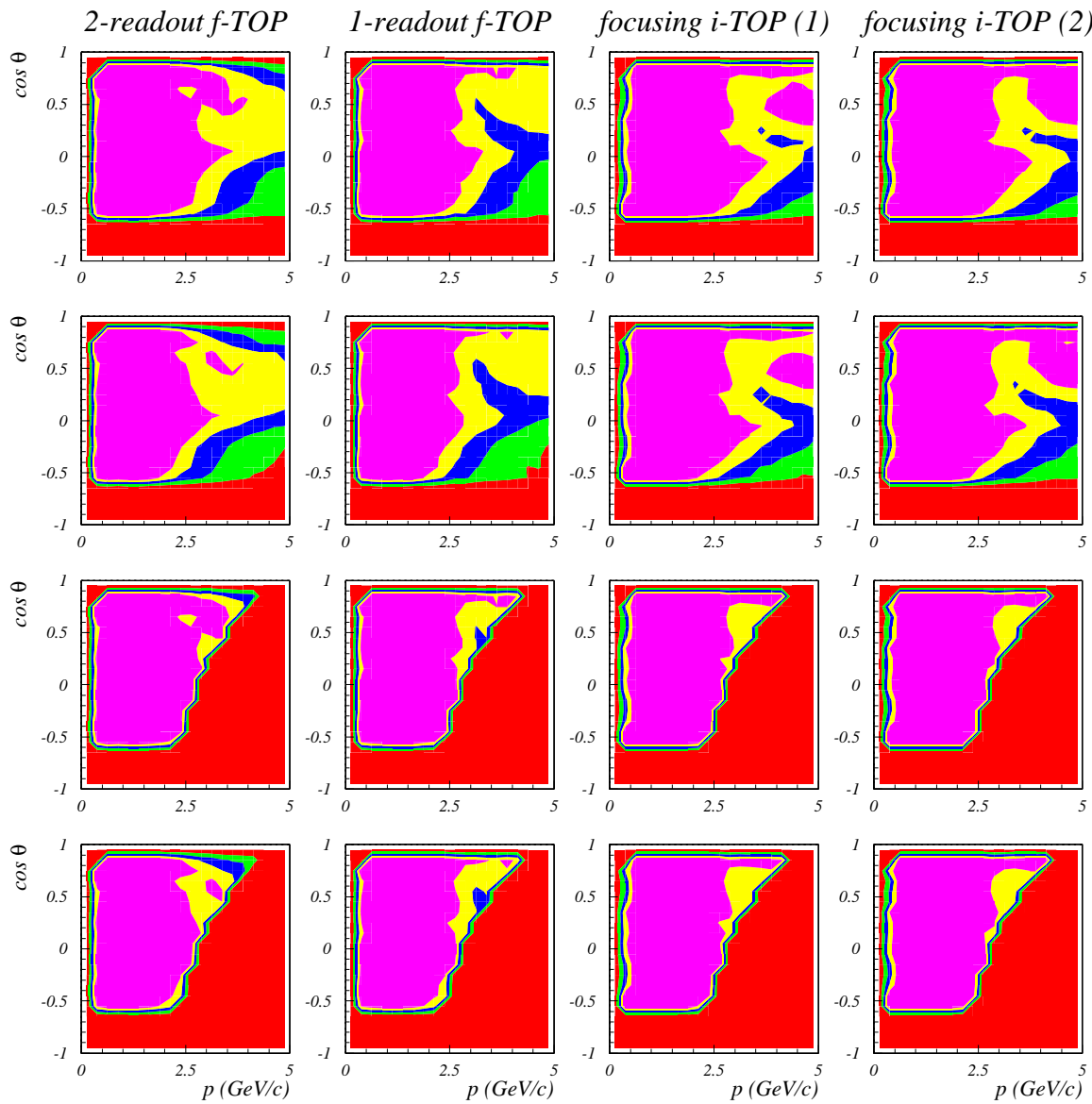
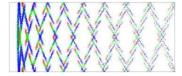


# Results: number of photons





# Results: separation power



SL-10, 1x4

$\sigma_{T_0} = 10\text{ps}$

$\sigma_{T_0} = 25\text{ps}$

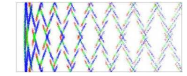
- $> 4\sigma$
- $> 3\sigma$
- $> 2\sigma$
- $> 1\sigma$

$\sigma_{T_0} = 10\text{ps}$

$\sigma_{T_0} = 25\text{ps}$

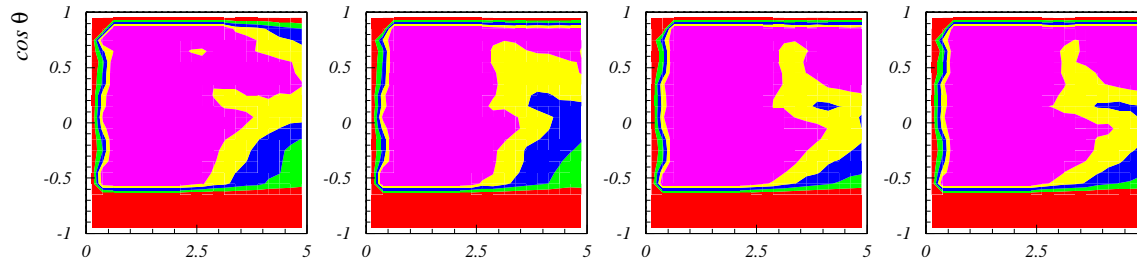


# Results: separation power

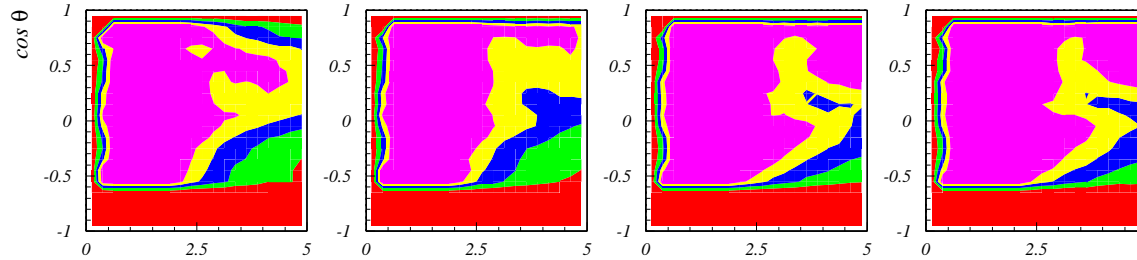


SL-10, 4x4

$\sigma_{T_0} = 10\text{ps}$

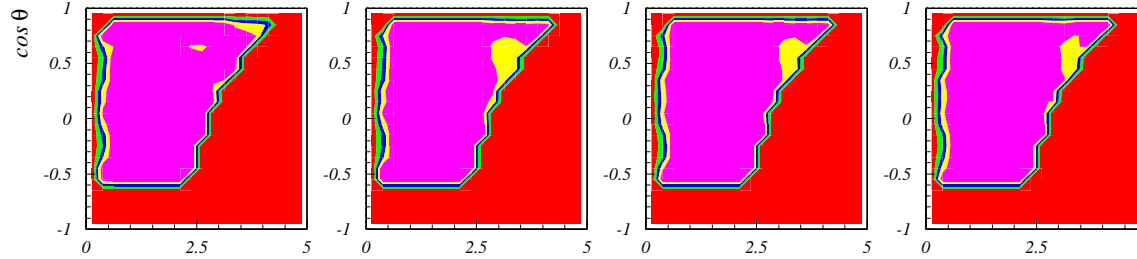


$\sigma_{T_0} = 25\text{ps}$

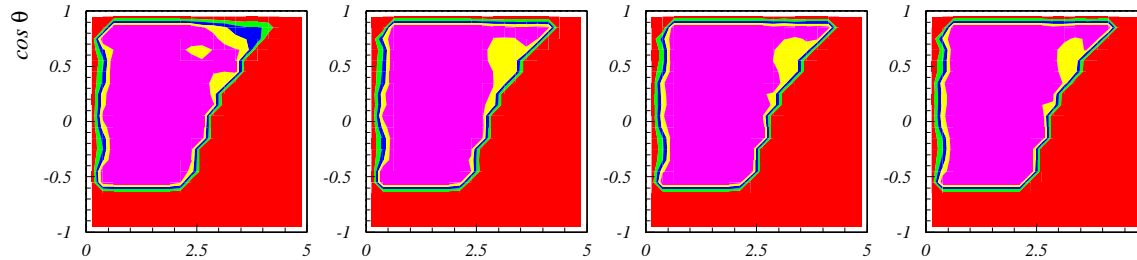


- $> 4\sigma$
- $> 3\sigma$
- $> 2\sigma$
- $> 1\sigma$

$\sigma_{T_0} = 10\text{ps}$



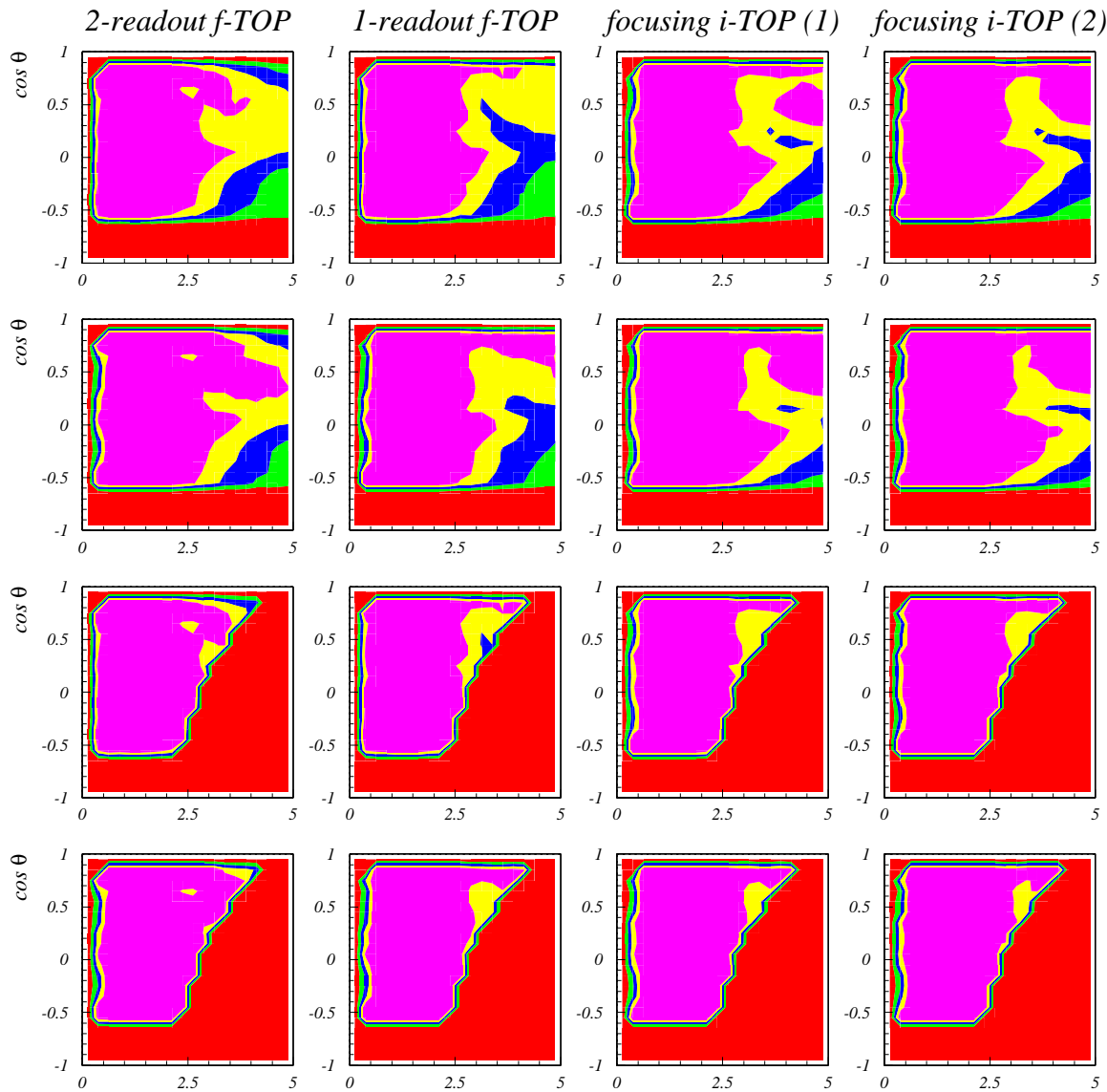
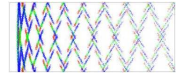
$\sigma_{T_0} = 25\text{ps}$







# Results: separation power



$\sigma_{T_0} = 10\text{ps}$

SL-10, 1x4

SL-10, 4x4

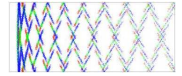
- $> 4\sigma$
- $> 3\sigma$
- $> 2\sigma$
- $> 1\sigma$

SL-10, 1x4

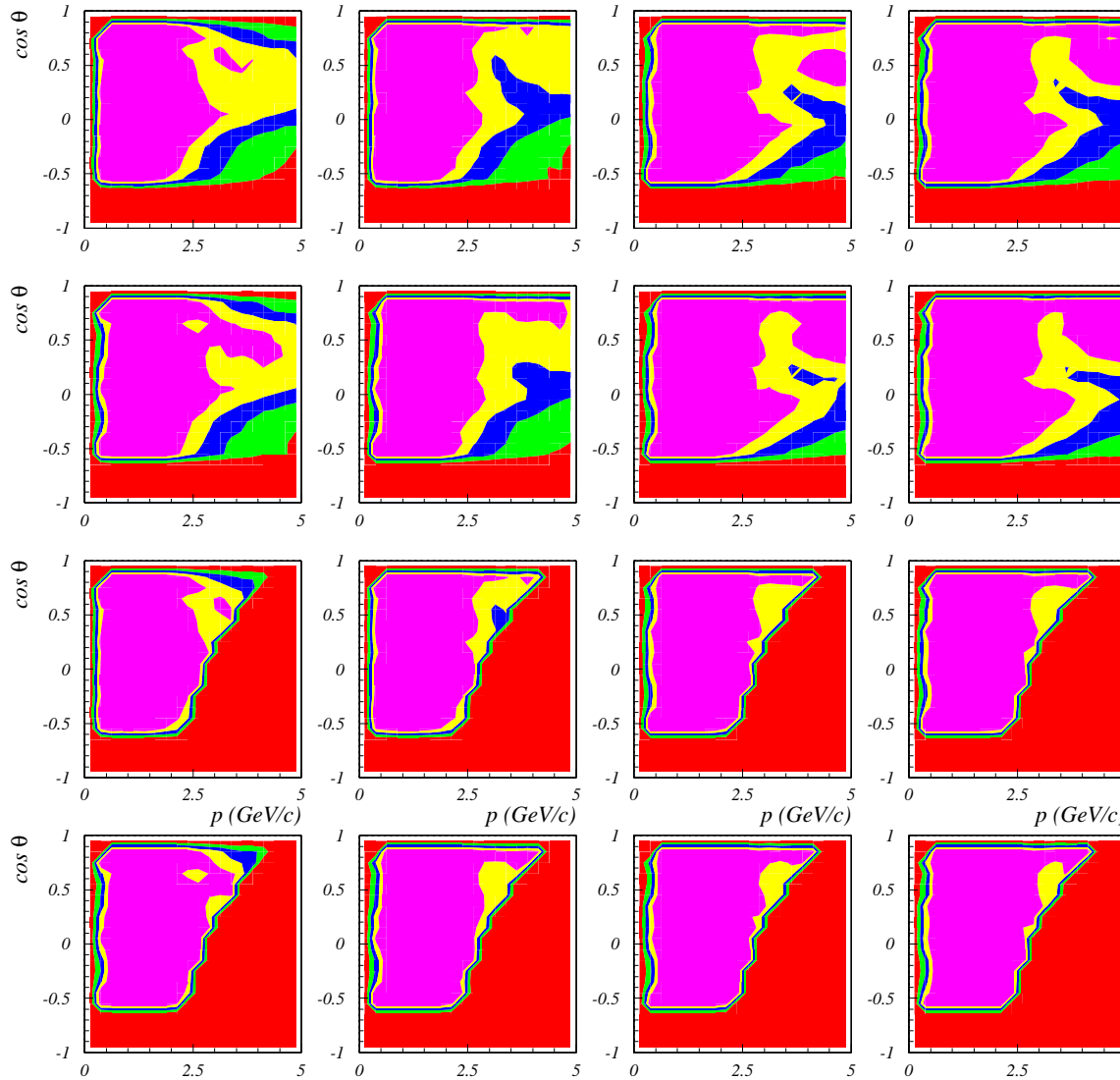
SL-10, 4x4



# Results: separation power



$\sigma_{T_0} = 25\text{ps}$



SL-10, 1x4

SL-10, 4x4

- $> 4\sigma$
- $> 3\sigma$
- $> 2\sigma$
- $> 1\sigma$

SL-10, 1x4

SL-10, 4x4