PARTNERSHIP
FOR ADVANCED COMPUTING
IN EUROPE

HMPP port

G. Colin de Verdière (CEA)

Overview

.Uchu prototype

HMPP

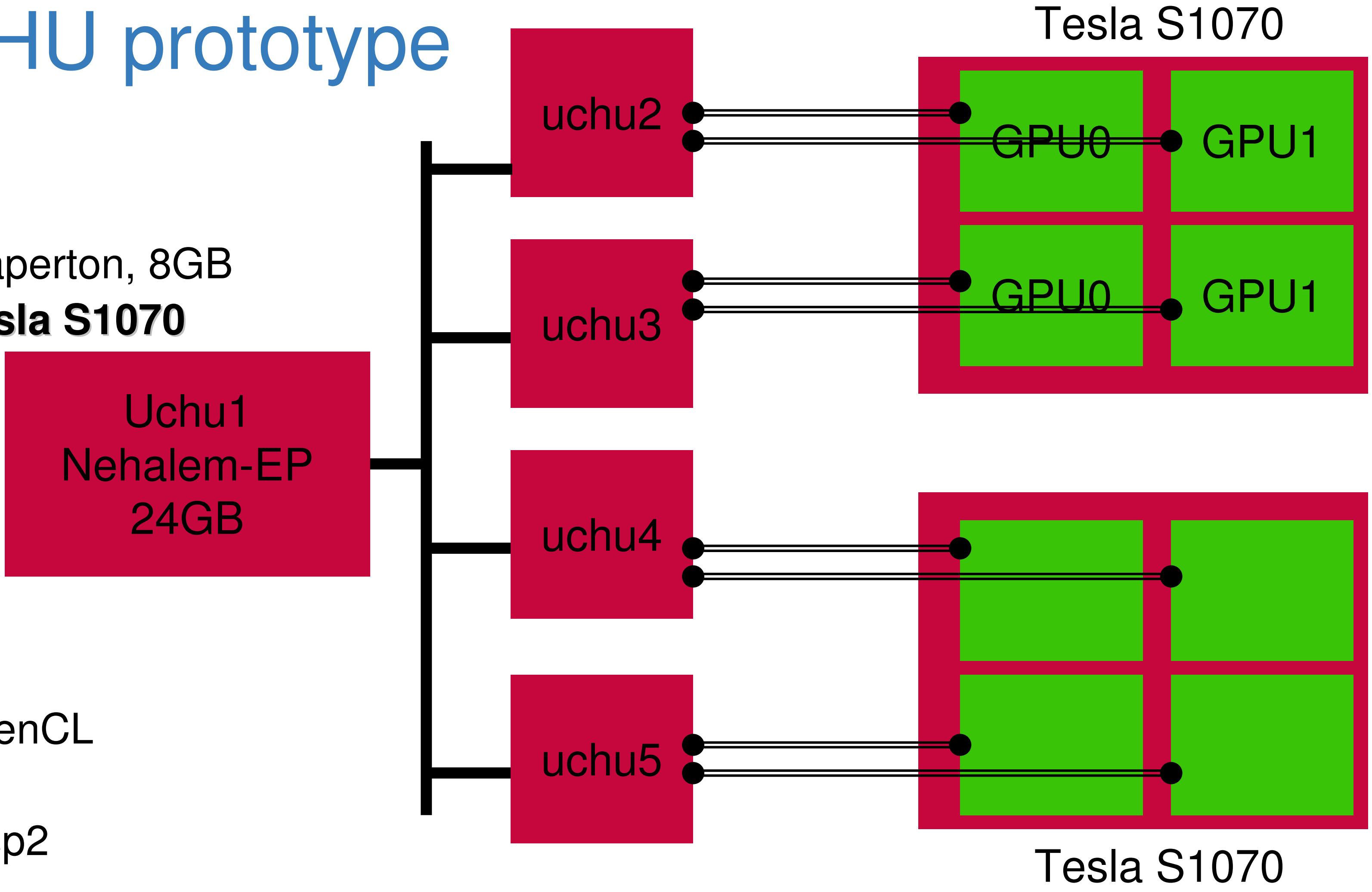
MOD2AS

MOD2AM

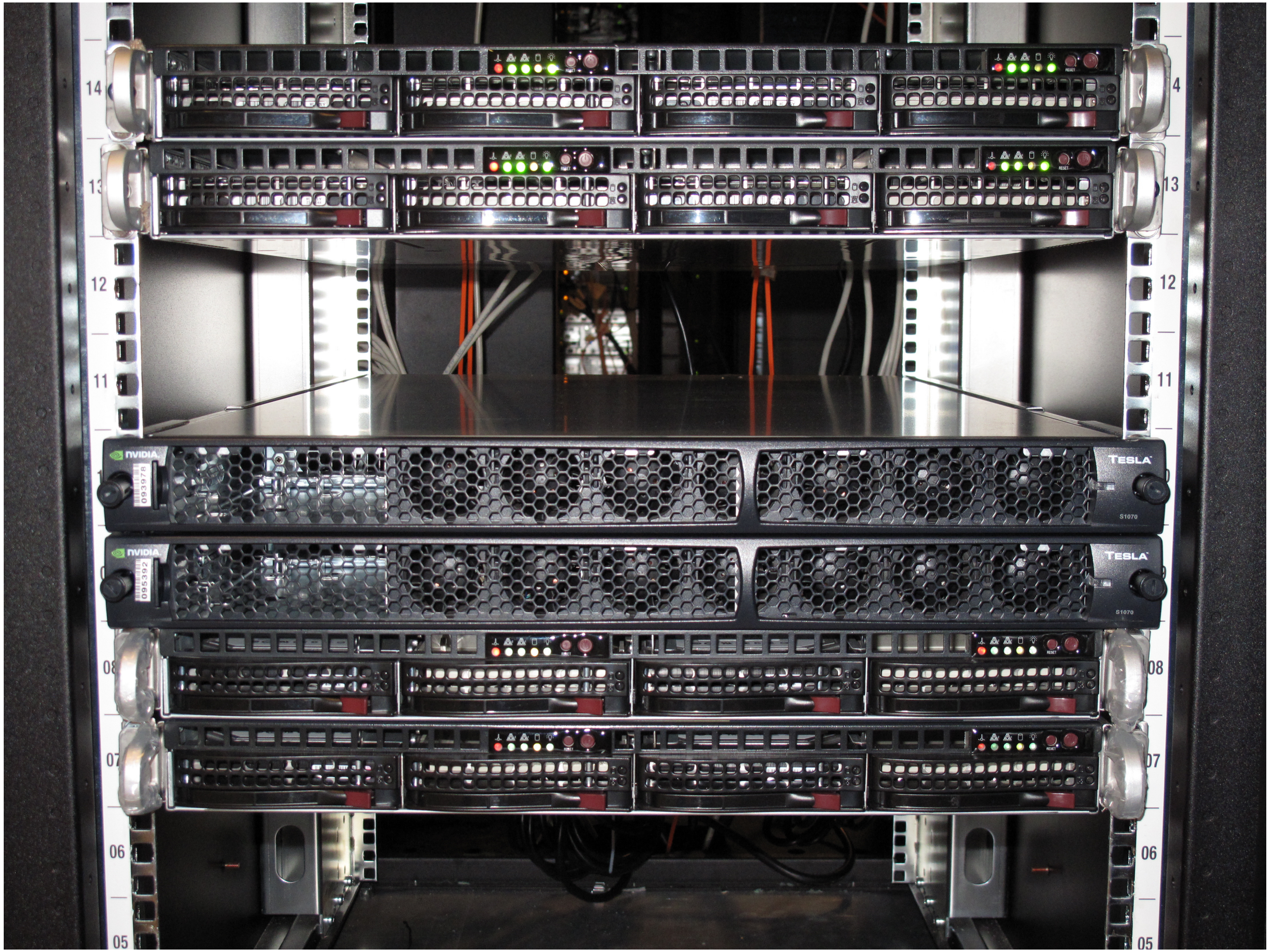
HMPP in a real code

The UCHU prototype

- Bull servers
  - 1 login node
  - 4 nodes 2 Haperton, 8GB
  - 2 **NVIDIA Tesla S1070**
  - IB DDR
- Slurm
- Software
  - gcc/icc/ifort
  - Cuda 2.3/OpenCL
  - Rapidmind
  - HMPP 2.2.1sp2



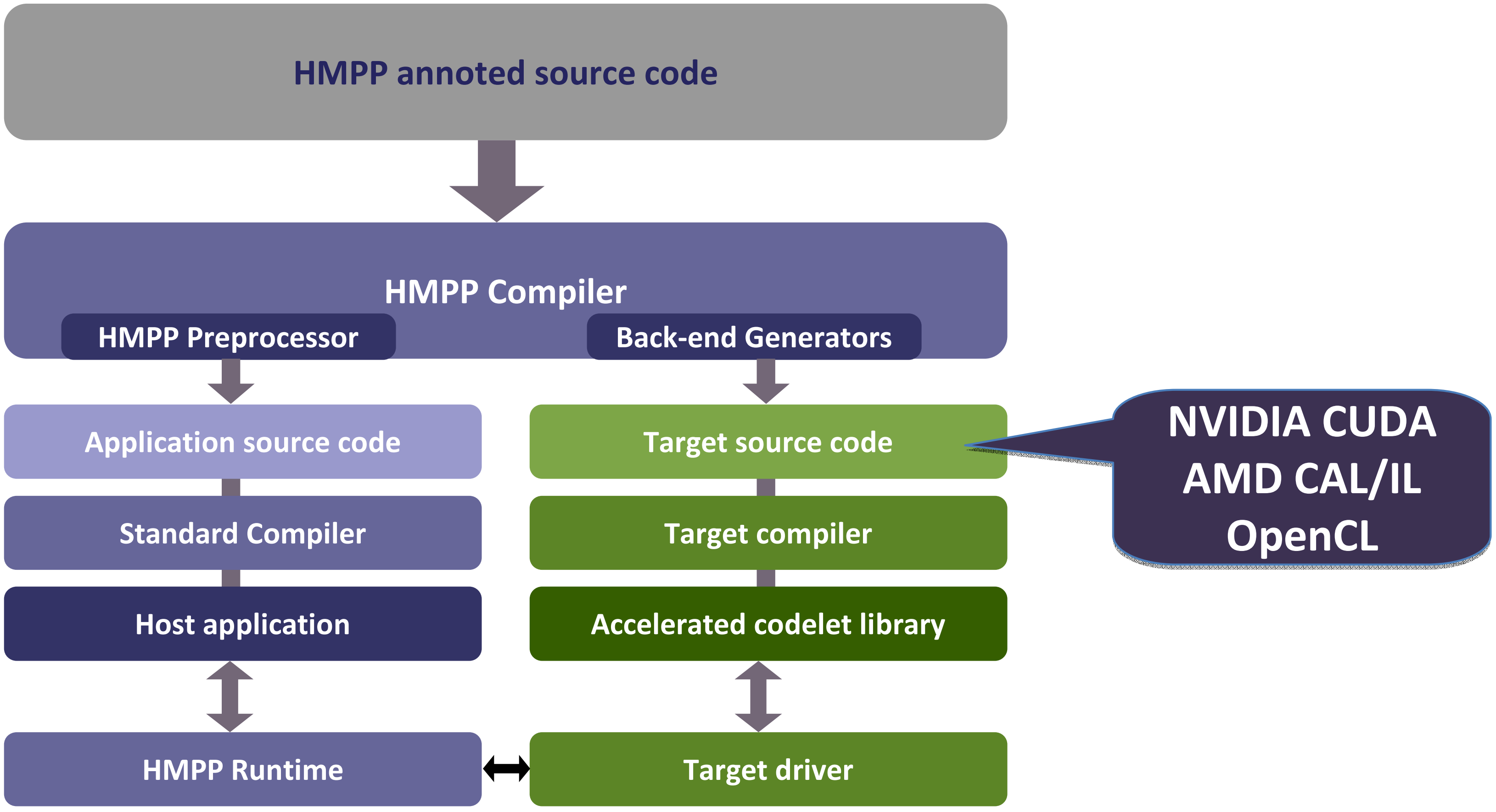
The real UCHU



HMPP

- HMPP is a high-level abstraction for manycore programming
- Takes annotated source code (pragma)
  - Keeps code portability
    - C & Fortran
- Has a low learning curve yet can reach significant performances
- Offers many high level features
  - Asynchronous data transfers and kernel execution
- Offers target oriented optimisations

HMPP: Compilation workflow



CPU GPU

HMPP: a small example

```
#pragma hmpp sgemm codelet, target=CUDA, args[vin1,vin2,vout].io=inout
void sgemm( int m, int n, int k, float alpha,
            float vin1[n][n], float vin2[n][n],
            float beta, float vout[n][n] ) {
 /* . . . */
}

int main(int argc, char **argv) {
    /* . . . */

 for( j = 0 ; j < NB_RUNS ; j++ ) {
#pragma hmpp sgemm callsite
    sgemm( size, size, size, alpha, vin1, vin2, beta, vout );
  }
    /* . . . */
 }
```

Declare codelet with CUDA target

Synchronous codelet call

HMPP: a more elaborate version

Preload data

```
int main(int argc, char **argv) {
    /* . . . */
#pragma hmpp sgemm allocate
    /* . . . */
#pragma hmpp sgemm advancedload, args[vin1;m;n;k;alpha;beta]
    /* . . . */

 for( j = 0 ; j < 2 ; j++ ) {
#pragma hmpp sgemm callsite &
#pragma hmpp sgemm  args[m;n;k;alpha;beta;vin1].advancedload=true
    sgemm( size, size, size, alpha, vin1, vin2, beta, vout );
    /* . . . */
 }

    /* . . . */
#pragma hmpp sgemm release
```

Avoid reloading data

MOD2AM: original code

```
void
mxm(int m, int l, int n, double
    a[m][l], double b[l][n], double
    c[m][n])
{
   int i, j, k, lf, mf;

   mf = m - m % 4;

   for (i = 0; i < mf; i += 4) {
      for (j = 0; j < n; j++) {
         c[i][j] = 0.0;
         c[i + 1][j] = 0.0;
         c[i + 2][j] = 0.0;
         c[i + 3][j] = 0.0;
      }   }
```

```
   lf = l - l % 4;
   for (i = 0; i < m; i++) {
      for (j = 0; j < lf; j += 4) {
         for (k = 0; k < n; k++) {
            c[i][k] = c[i][k]
               + a[i][j + 0] * b[j + 0][k]
               + a[i][j + 1] * b[j + 1][k]
               + a[i][j + 2] * b[j + 2][k]
               + a[i][j + 3] * b[j + 3][k];
         }     }    }

   for (i = 0; i < m; i++) {
      for (j = lf; j < l; j++) {
         for (k = 0; k < n; k++) {
               c[i][k] = c[i][k] + a[i][j] *
   b[j][k];
      }    }    }
} // mxm
```

MOD2AM: HMPP version – main()

```
#pragma hmpp Hmxm advancedload, args[a;b], args[a].size={m,l},
   args[b].size={l,n}
for (i = 0; i < nrep; i++) {
#pragma hmpp Hmxm callsite, args[a;b].advancedload=true
   mxm(m, l, n, (double (*)[m]) a, (double (*)[n]) b, (double
   (*)[n]) c);
}
#pragma hmpp Hmxm delegatedstore, args[c]
time = cclock() - time;
ok = check(m, l, n, (double (*)[n]) c);
```

MOD2AM: mxm.h

```
#pragma hmpp Hmxm codelet,
  args[a;b].io=in, args[c].io=out,
  TARGET=CUDA, args[a].size={m,l},
  args[b].size={l,n}, args[c].size={m,n}

void mxm(int m, int l, int n, double
  a[m][l], double b[l][n], double
  c[m][n]);
```

MOD2AM: mxm.c optimized

```
#include ‘’ mxm.h ‘’
void mxm (int m, int l, int n, const double
   a[m][l], const double b[l][n],
double c[m][n])
{
   #define HUNROLL 2
   int i, j, k, lf, mf;
   int rest = n % HUNROLL;
   for (i = 0; i < m; i++) {
        for (j = 0; j < n; j++) {
                c[i][j] = 0.0;
        }
   }
```

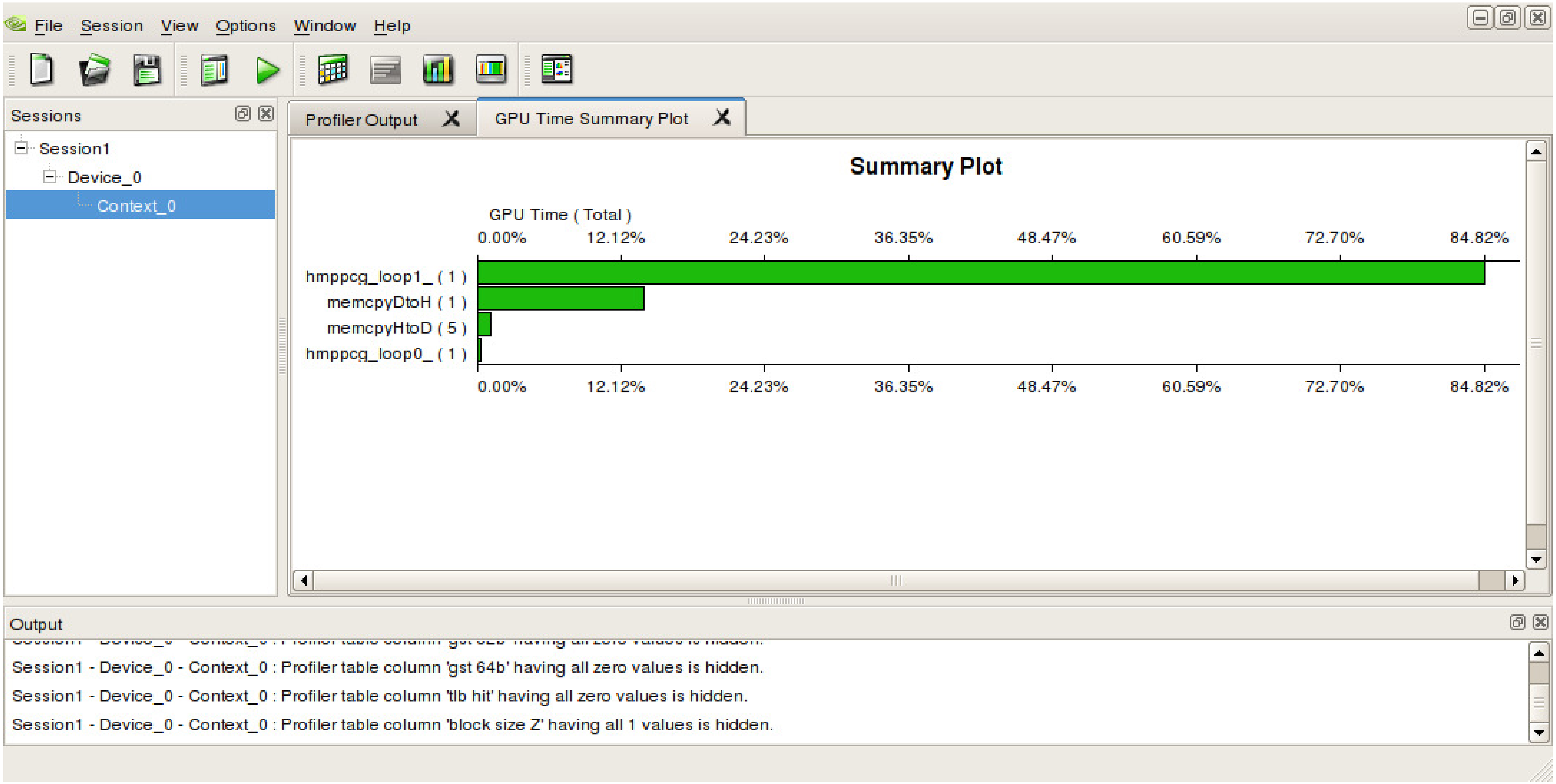
```
#pragma hmppcg unroll(6), jam(k)
for (i = 0; i < m; i++) {

#pragma hmppcg unroll(2), split, noremainder
   for (k = 0; k < n - rest; k++) {
        double prod = 0.0;
        double va, vb;
        j = 0;
        va = a[i][j]; // trick: prefetching of arrays a and b
        vb = b[j][k];
        for (j = 1; j < l; j++) { // prefetching: index 0 has been loaded
                prod += va * vb;
                va = a[i][j];
                vb = b[j][k];
        }
        prod += va * vb; // prefetching: don’t forget the last index
        c[i][k] += prod;
   }
}
```

```
  if (rest) {      // leftovers using the same trick
      for (i = 0; i < m; i++) {
            for (k = n - rest; k < n; k++) {
                   double prod = 0.0;
                   double va, vb;
                   j = 0;
                   va = a[i][j];
                   vb = b[j][k];
                   for (j = 1; j < l; j++) {
                          prod += va * vb;
                          va = a[i][j];
                          vb = b[j][k];
                   }
                   prod += va * vb;
                   c[i][k] += prod;
      }}
  }
}
```

MOD2AM: results on uchu (78GF DP peak)

```
env HMPPCG_FLAGS="--cuda-block-size 64x1" ccc_mprun ./h.mod2am
    10 |   10 |    10|     0.0317 |       0.06 |  T |
    20 |   20 |    20|     0.0021 |       7.62 |  T |
    50 |   50 |    50|     0.0052 |      48.18 |  T |
   100 |  100 |   100|     0.0103 |     193.81 |  T |
   192 |  192 |   192|     0.0173 |     817.62 |  T |
   200 |  200 |   200|     0.0262 |     610.66 |  T |
   500 |  500 |   500|     0.0609 |    4107.86 |  T |
   512 |  512 |   512|     0.0639 |    4201.46 |  T |
   576 |  576 |   576|     0.0642 |    5954.20 |  T |
  1000 | 1000 |  1000|     0.1221 |   16381.76 |  T |
  1024 | 1024 |  1024|     0.1254 |   17129.71 |  T |
  2000 | 2000 |  2000|     0.4590 |   34854.74 |  T |
  2048 | 2048 |  2048|     0.5092 |   33741.00 |  T |
  5000 | 5000 |  5000|     6.5653 |   38078.93 |  T |
 10240 |10240 | 10240|    53.3472 |   40254.82 |  T |
 12096 |  576 | 12096|     4.7198 |   35711.70 |  T |
 12096 | 1152 | 12096|     8.2283 |   40968.88 |  T |
```



```
Session1 - Device_0 - Context_0 : Profiler table column 'gst 64b' having all zero values is hidden.
Session1 - Device_0 - Context_0 : Profiler table column 'tlb hit' having all zero values is hidden.
Session1 - Device_0 - Context_0 : Profiler table column 'block size Z' having all 1 values is hidden.
```

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MOD2AS: original code

```
#endif
void
SPMXV(int ncols, int nrows, int nelmts, int indx[nelmts], int rowp[nrows],
REAL matvals[nelmts], REAL invec[ncols], REAL outvec[nrows])
{
int i, j, nrest;
for (i = 0; i < nrows; i++)
        outvec[i] = (REAL) 0.0;
for (i = 0; i < nrows - 1; i++) {
        nrest = (rowp[i + 1] - rowp[i]) % 4;
        for (j = rowp[i]; j < rowp[i + 1] - nrest; j += 4) {
                outvec[i] = outvec[i] + (matvals[j] * invec[indx[j]])
                        + matvals[j + 1] * invec[indx[j + 1]]
                        + matvals[j + 2] * invec[indx[j + 2]]
                        + matvals[j + 3] * invec[indx[j + 3]];
        }
        for (j = rowp[i + 1] - nrest; j < rowp[i + 1]; j++) {
                outvec[i] = outvec[i] + matvals[j] * invec[indx[j]];
        }
}
for (j = rowp[nrows - 1]; j < nelmts; j++) {
        outvec[nrows - 1] = outvec[nrows - 1] + matvals[j] * invec[indx[j]];
}
}
```

MOD2AS: main()

```
#define LOOPS 1
for (j = 0; j < LOOPS; j++) {
   for (i = 0; i < nrows; i++)
        outvec[i] = (REAL) 0.0;
#pragma hmpp Hspmxv callsite
   spmxv(ncols, nrows, nelmts, indx, rowp, matvals,
   invec, outvec);
   time = cclock() - time;
}
time /= LOOPS;
ok = check(ncols, nrows, nelmts, indx, rowp, outvec);
```

MOD2AS: spmxv.c

```
void
spmxv(int ncols, int nrows, int nelmts, int
   indx[nelmts], int rowp[nrows],
double matvals[nelmts], double invec[ncols], double
   outvec[nrows])
{
int i, j, k;
int start, end;
int nrest = 0;
int warpoff = 0;
double somme = 0.;
#define SIZE 32*2
double partial[nrows * SIZE];
for (i = 0; i < nrows; i++) {
   outvec[i] = (double) 0.0;
}
```

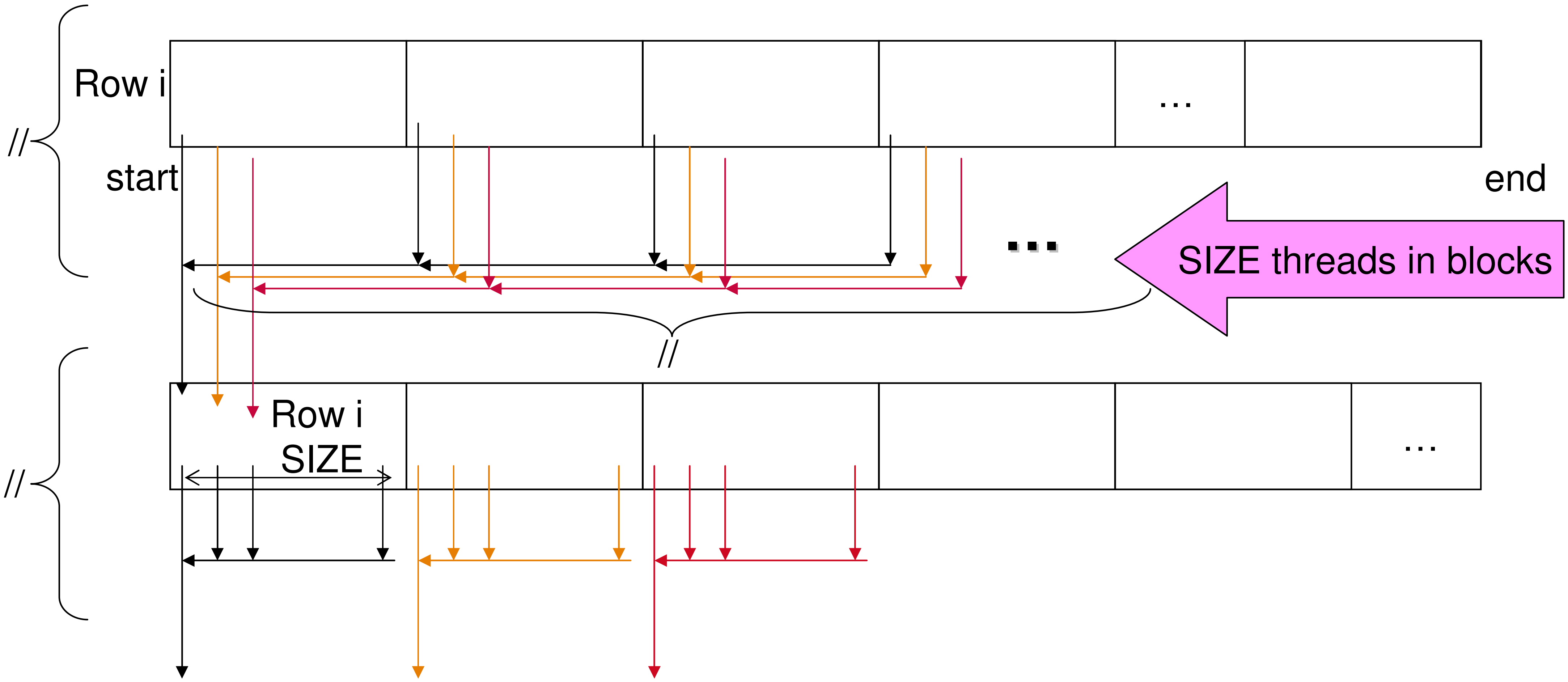
2D
Grid

```
// do partial sums in // taking warp sizes into account
for (i = 0; i < nrows; i++) {
  for (warpoff = 0; warpoff < SIZE; warpoff++) {
      start = rowp[i];
      if (i == (nrows - 1)) { end = nelmts;
      } else { end = rowp[i + 1]; }
      somme = 0;
      // partial reduction
      for (j = start + warpoff; j < end; j += SIZE) {
            somme += (matvals[j] * invec[indx[j]]);
      }
      partial[i * SIZE + warpoff] = somme;
  } // for warpoff
} // for i
```

1D Grid

```
  // finish summing
  for (i = 0; i < nrows; i++) {
    somme = 0.;
    for (k = 0; k < SIZE; k++) {
        somme += partial[i * SIZE + k];
    }
    outvec[i] = somme;
  }
} // spmxv
```

Memory access for mod2as



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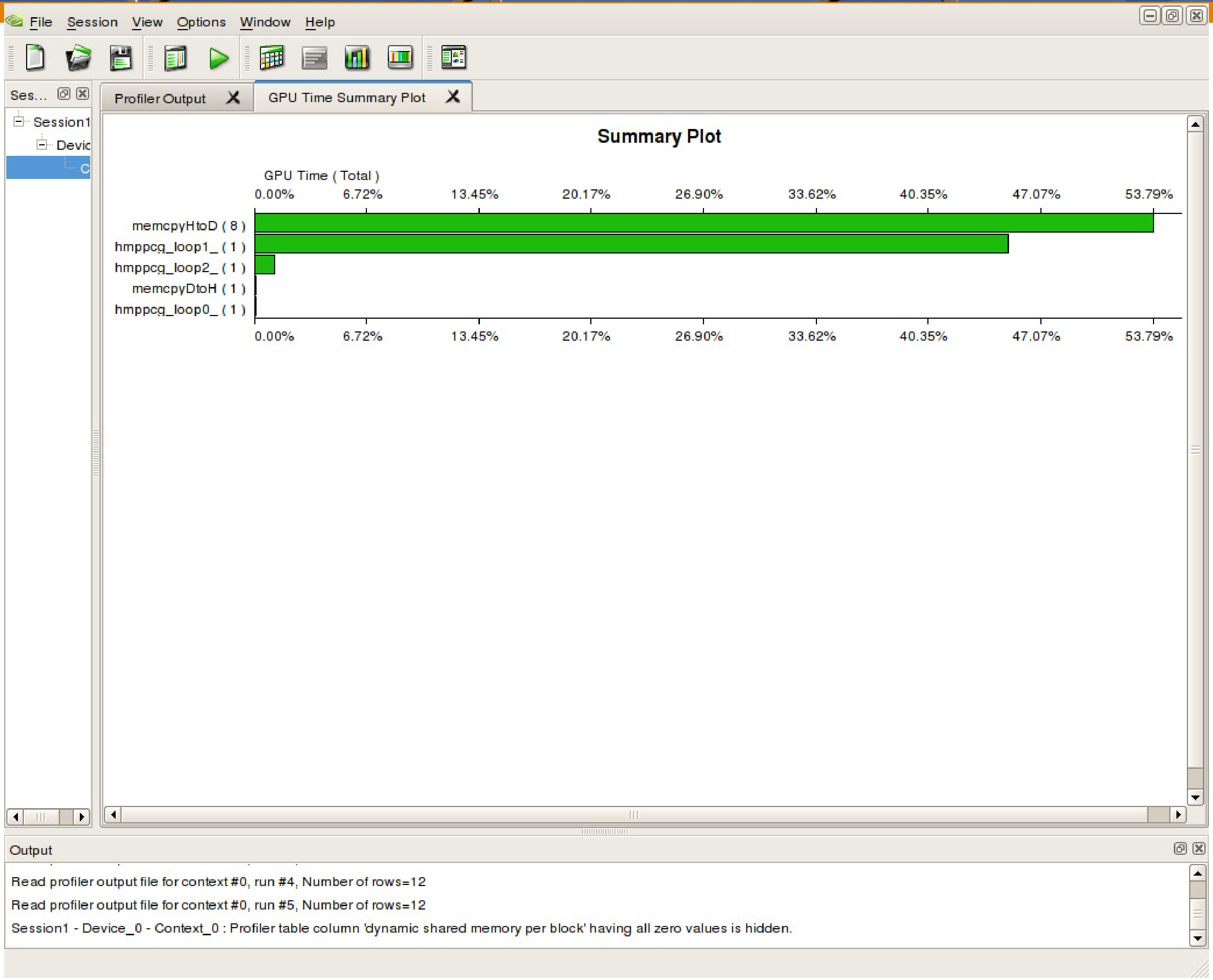
MOD2AS: results on Uchu

```
Program mod2as: Sparse (CRS) Matrix-vector Multiply
-------------------------------------------------------
 #Rows | #Cols | %Fill |    Time(s)     |    Mflop/s    |OK|
-------------------------------------------------------
    100|     100|  3.50 |          3.1903|           0.000|  T|
    200|     200|  3.75 |        0.086699|           0.035|  T|
    256|     256|  5.00 |        0.086522|           0.076|  T|
    400|     400|  4.38 |        0.086425|           0.162|  T|
    500|     500|  5.00 |        0.086643|           0.289|  T|
    512|     512|  4.00 |        0.087014|           0.241|  T|
    960|     960|  4.50 |         0.08711|           0.953|  T|
   1000|    1000|  5.00 |        0.087103|           1.148|  T|
   1024|    1024|  5.50 |        0.087619|           1.316|  T|
   2000|    2000|  7.50 |        0.098915|           6.066|  T|
   4096|    4096|  3.50 |         0.10218|          11.494|  T|
   4992|    4992|  4.00 |        0.096131|          20.738|  T|
   5000|    5000|  4.00 |         0.09598|          20.838|  T|
   9984|    9984|  4.50 |         0.12392|          72.392|  T|
  10000|   10000|  5.00 |         0.12724|          78.593|  T|
  10240|   10240|  5.72 |         0.13471|          89.077|  T|
```

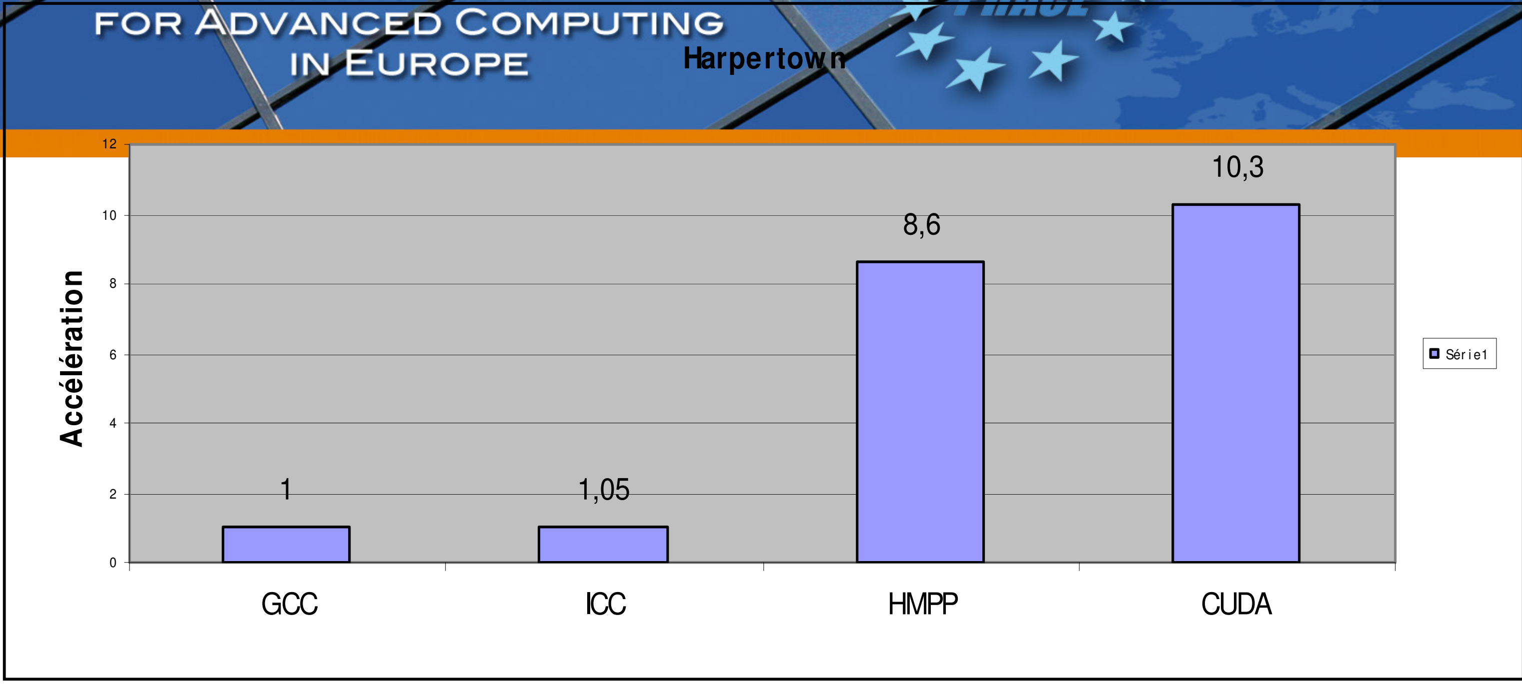


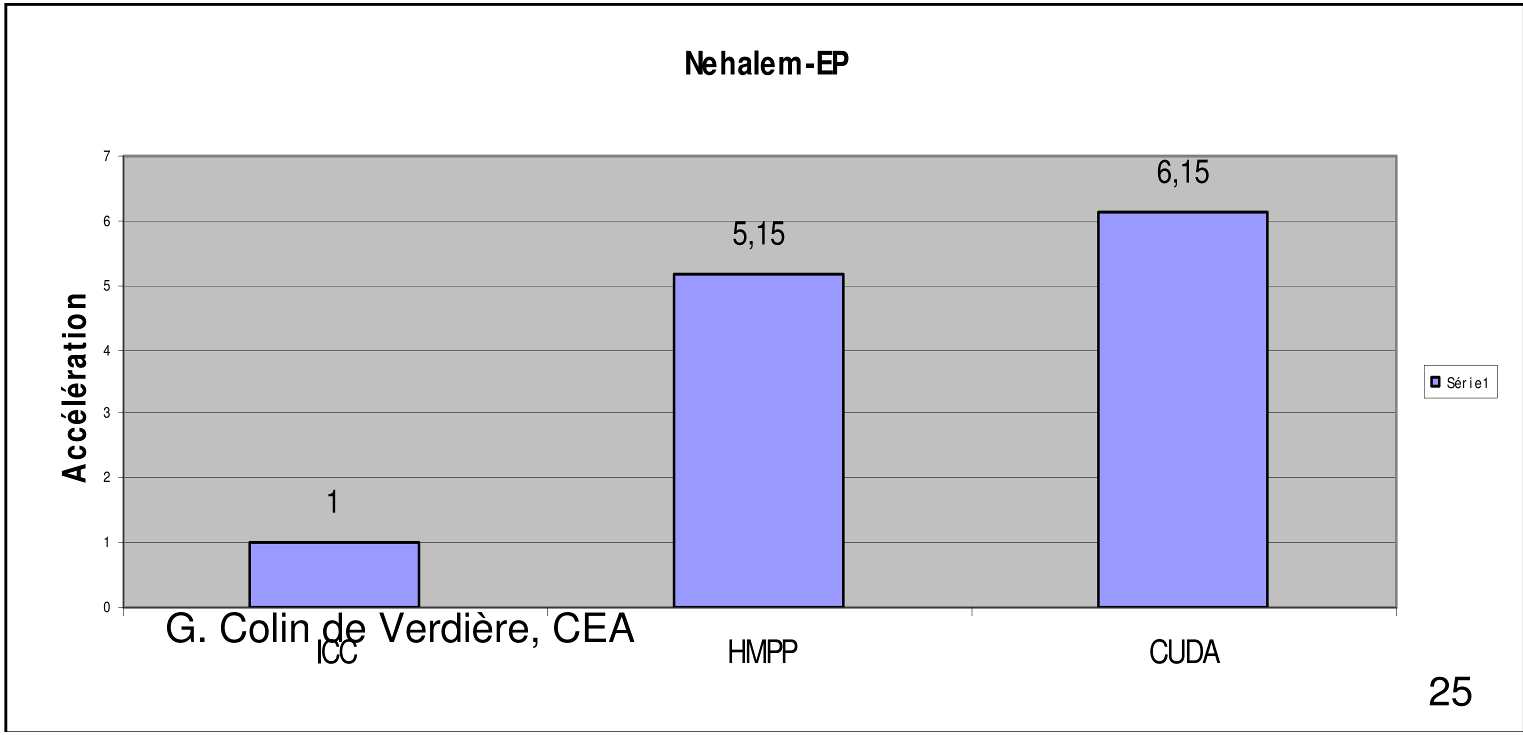
```
Read profiler output file for context #0, run #4, Number of rows=12
Read profiler output file for context #0, run #5, Number of rows=12
Session1 - Device_0 - Context_0 : Profiler table column 'dynamic shared memory per block' having all zero values is hidden.
```

HMPP in a real code

- Test case =10000x10000, 10 iterations
  - DP

Harpertown 2.800Ghz 1626s gcc
Harpertown 2.800Ghz 1540.583s icc
Nehalem EP 2.933GHz 975.590s icc
Tesla T10 1.3GHz 189.087s HMPP
Tesla T10 1.3GHz 158.621s CUDA





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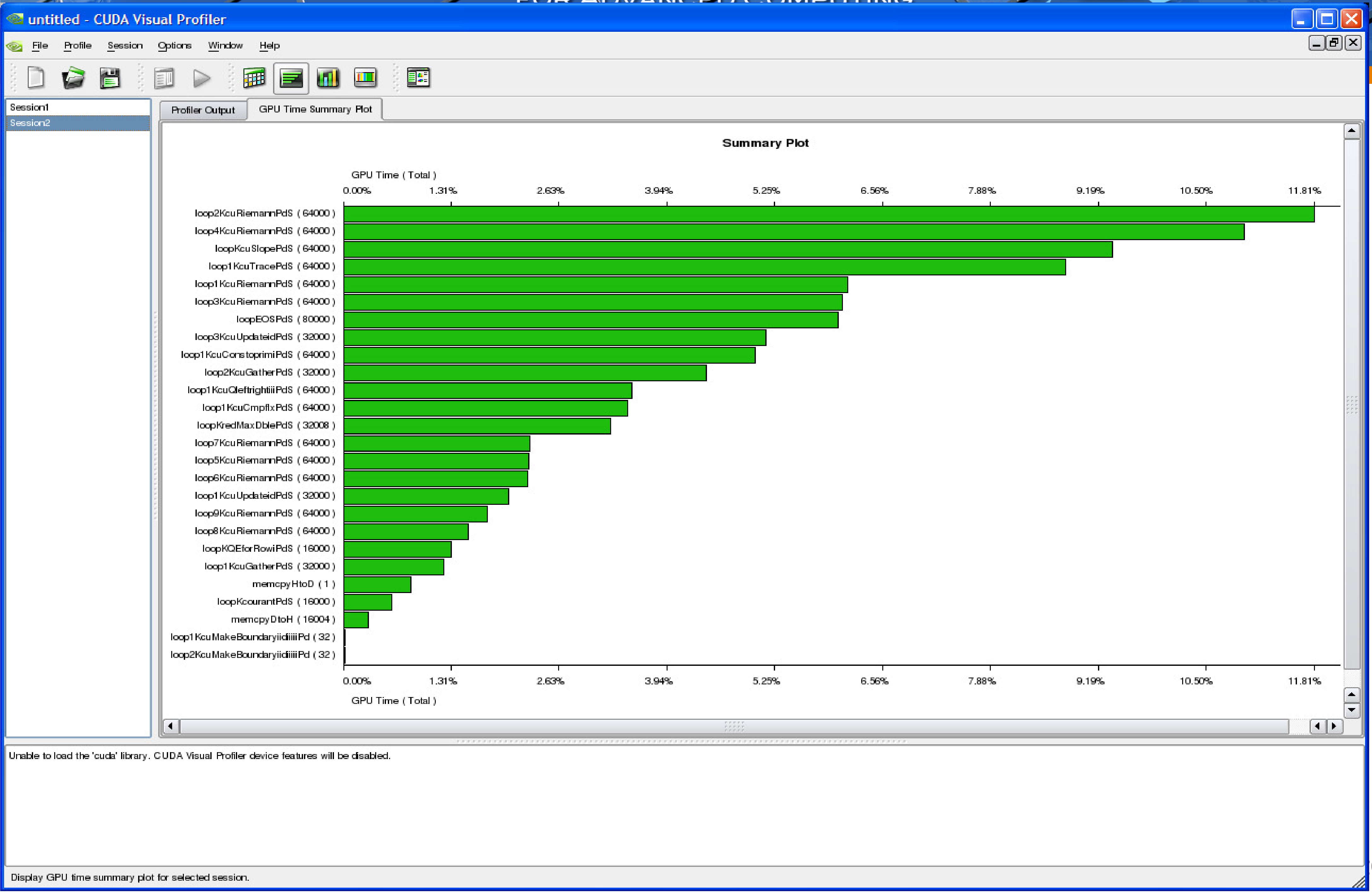

Unable to load the 'cuda' library. CUDA Visual Profiler device features will be disabled.

Display GPU time summary plot for selected session.

HMPP port : some conclusions

- Kernels are important to understand a language
  - Yet only full applications can exercise a language
    - Only a small part of HMPP has been tested here

- Port to HMPP is easy
  - The difficulty lies in the data movements

- HMPP allows for decent performances in real cases
  - Asynchronous transfers and calls are key for performance